PB-227 589

SHELLFISH SANITATION-WATER QUALITY ON U.S. CANADIAN INTERNATIONAL BOUNDARY-ST. CROIX RIVER

National Center for Urban and Industrial Health
Cincinnati, Ohio

11 April 1966

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ST. CROIX RIVER

A REVIEW

SHELLFISH SANITATION-WATER QUALITY

on

U.S.-CANADIAN INTERNATIONAL BOUNDARY

11 April 1966

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NATIONAL TECHNICAL
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U S Department of Commerce
Springfield VA 22151

Prepared by

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Urban and Industrial Health
Water Supply and Sea Resources Program

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FOREWORD

The National Shellfish Sanitation Program represents an unusual cooperative arrangement of not only State and Federal agency resources within the United States but even operates on the basis of international agreements. One such agreement was entered into with Canada on April 30, 1948, and places shellfish sanitation in the two countries on an equal basis.

The goals of the National Shellfish Sanitation Program are: (1) the continued safe use of this natural resource and (2) active encouragement of water quality programs which will preserve all possible coastal areas for this beneficial use.

Any action involving this second goal results not only in cooperative action with the Federal Water Pollution Control Administration but in the case of boundary waters with Canada the International Joint Commission which was established according to the Boundary Waters Treaty of 1909. On June 10, 1955, in accordance with the procedures provided in Article IX of the treaty of 1909, the Governments of the United States and Canada united in a "Reference" to the International Joint Commission for the purpose of conducting studies to determine whether greater use might be made of the waters of the St. Croix Basin.

The information and technical data utilized in this report comes from several of the reports prepared for the International Joint Commission and the material has been used in keeping with the goals of the National Shellfish Sanitation Program and the cooperative agreement with Canada applicable to that program.

The water quality considerations reviewed in this report are related solely to man-made pollution effects and as such do not in any way deal with the natural toxins in the same area often referred to as Paralytic Shellfish Poison or PSP.

Our appreciation is extended to the many persons who provided the available resource materials and contributed their time and opinions to permit as comprehensive a review as possible.

Ronald G. Macomber

Ronald G. Macomber
Associate Director
Field Research and Development
Northeast Research Center

INTRODUCTION

> "Less is known about the course of events when contaminants reach the hydrosphere. Streams, rivers, lakes, ground water, and estuaries have not yet been studied intensively enough to permit reliable predictions of what happens to pollutants. Only in a gross sense can effects on the biosphere be foreseen for a few cases of crassly poisonous or choking substances."
>
> "Within many of the sciences, or sub-sciences, there are important gaps in real understanding. As these gaps become clearer to us, we also recognize that we have volumes of data on certain variables, and completely inadequate data on others."
>
> "In deciding how he can provide useful know-how, the scientist finds (as usual) that he must make more studies -- which require more data."
>
> (Waste Management and Control -- National Academy of Sciences, National Research Council Pub. 1400; -- 1966)

The above quotations taken from two separate parts of the reference publication concisely describe the situation faced by the Field Research and Development Staff of the Northeast Research Center when asked to recommend steps to be taken to "establish the water quality needs for shellfish culture in the subject waters along with recommendations needed to assure such quality requirements." Perhaps the "key" question revolved about the "gaps" in information and should more studies (as usual) be recommended.

Based upon observations of many of the participating units of the National Shellfish Sanitation Program it appears that in many situations it is easier to conduct field studies than it is to collect and review the vast amounts of data already collected on past surveys and from related sources such as the U.S. Geological Survey stream data and Weather Bureau data. This review and analysis has been designed to give some indication of what may be done with data, not necessarily collected for direct application in the shellfish sanitation program, and by means of analysis which may readily be utilized by any of the units participating in the national program as part of a public health activity.

SUMMARY

Considering the present crude predicti on methods ample data was available upon which to make a preliminary determination of the pollution effect upon the principal resource area (Oak Bay).

The Soft-Shell Clam (Mya arenaria) is the only shellfish included in the National Shellfish Sanitation Program that is here considered of commercial value. In the 1940's a reported annual production of 200,000 pounds came from the now closed areas in Canada. There are only isolated small areas of potential shellfish resource known for the United States portion.

The major potential production area in Canada (Oak Bay) is affected primarily by the pollution coming down the St. Croix River and upper Estuary.

Based upon the admittedly crude prediction methods presently available, it appears that in order to provide continuous safety for this shellfish area it would be necessary to first provide separate sewer systems for all community sewer collection systems starting with the communities of Princeton and Grand Falls and including all others on down the river and estuary. Second, it would then be necessary to provide what is termed secondary sewage treatment and chlorination, or equivalent, for all such sewage that is collected.

At best the area would then be classified as "Conditionally Approved[1]." Only after post-construction surveys would it be possible to determine whether this condition would also have to be related to seasonal factors.

As is the case with all shellfish growing area studies and analysis, the hardest to determine or predict and the most critical part of the classification procedure is the determination of the "area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions." This review of the St. Croix is intended to give some of the steps currently available for this type of determination and prediction which may be included in present shellfish sanitation surveys of growing areas intended for a safe "raw" food product.

[1] "Conditionally Approved" -- Waters approved by the control agencies for growing and/or harvesting of shellfish; approval being contingent upon the attainment of an established performance standard by sewage treatment works discharging effluent, directly or indirectly, to the area.

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CHAPTER I

BRIEF DESCRIPTION OF ST. CROIX ESTUARY AREA

Perhaps the two most unique features about the St. Croix estuary are the political and tidal situations. The estuary serves, as does much of the river above it, as the international boundary with Canada. This is the only east coast, United States situation wherein common waters serve as shellfish growing areas in two countries. The tidal range accounts for some of the highest experienced anywhere in the entire United States shellfish-producing areas.

Physical Description (See Figures I-1 and IV-1.)

The pertinent physical description items are best quoted from the primary reference, "Passamaquoddy Fisheries Investigations -- Report to International Joint Commission -- Appendix I -- Oceanography -- October 1959":

> "The main features of the bottom of Passamaquoddy Bay were probably shaped by ice. The St. Croix estuary undoubtedly held a valley glacier. The ice sheet moving in from the north resulted in the shallow, gently sloping, northern part of the Bay and the steeply sloping, deeper zone, along the Pre-Cambrian contact from the northern side of Deer Island to Midjik Bluff.
>
> "The valley glacier of the St. Croix estuary probably extended into Western and Head Harbor Passages and gave rise to the irregular bottom profiles.
>
> "The St. Croix estuary above St. Andrews has an average depth below low water of 38 ft. The low water area is 10 sq. mi. (square nautical miles) exposing 3 sq. mi. of intertidal mud flats. A channel 100 - 130 ft. in depth runs from the mouth of the estuary to within one-half mile of Oak Bay. (Fig. I-1.) The bottom profile is irregular throughout.

"In the Quoddy Region tides and their associated currents are relatively important oceanographically because of their considerable magnitude. The tides of the Bay of Fundy are an anomolistic type, that is '...the change in the moon's distance has more influence upon the tide than the change of the moon's phases. The difference in the range of the tide, at perigee and apogee, is thus greater than the difference in range at the average spring and neap tides ...' (Bay of Fundy Tide and Current Tables, 1958). Tides in the Bay of Fundy range from 15 ft. at the mouth to 60 ft. at the head and are among the highest in the world. In the Quoddy Region, the maximum range is approximately 30 ft. Mean tidal ranges vary from 20 ft. at the head of the St. Croix estuary to 17 ft. at North Head, Grand Manan. Spring tidal ranges are 24 ft. at North Head, Grand Manan, and 28 ft. at St. Stephen (Bay of Fundy Tide and Current Tables, 1958).

"Most of the fresh water inflow to the Inner Quoddy Region comes from three rivers, St. Croix, Magaguadavic and Digdeguash, which discharge into Passamaquoddy Bay at a mean annual rate of approximately 4,000 cfs. The St. Croix River is largest and discharges about as much as the Magaguadavic and Digdeguash Rivers combined."

"Fresh water discharge varies widely both seasonally and annually. In general, peak periods of river discharge occur twice each year. A curve constructed from average monthly values during the past 34 years ... shows that the St. Croix River discharge reaches a monthly maximum of 4461 cfs in April during the spring freshet and a monthly minimum of 1539 cfs in September. A second but much smaller peak appears in November or December."

At this point as we start to move inland in our area description it is best to turn to quotations from the second reference for this section of the report, namely: "New England Drainage Basins -- Federal Security Agency -- Public Health Service, Water Pollution Series No. 7 - 1951":

"The St. Croix River is formed by the confluence of the East Branch and the West Branch, both of which have their origin in large lakes. The total length of the river,

including both branches, is 100 miles of which nearly three-fourths forms the international boundary line with Canada. The drainage area of the sub-basin in Maine is about 1,100 square miles.

"Elevations in the sub-basin are generally low. There are numerous lakes throughout the watershed, of which the Grand Lake system is a part. Lakes account for more than nine percent of the watershed area in Maine; about 10 percent is in pasture or crops, and the remainder is in heavy forest or cut-over woodland. Bedrock formation is almost entirely granite and limestone. The only soil suitable for agriculture lies along the lower reaches of the river.

"The average annual precipitation is about 41 inches with slightly more rainfall occurring during the fall months. The average summer temperature is near 65°F and winter temperature averages 16° to 20°F. There are only two large tributaries to the St. Croix River -- the West Branch and the upper St. Croix River or East Branch. The average run-off from the Maine portion of the sub-basin during 27 years of record averaged about 1,775 cubic feet per second."

Area Development

The description of the development on the United States side of the international boundary is best quoted from the same New England Drainage Basin Report:

"The sub-basin includes only four communities over 1,000 population, the largest being Calais with an estimated 1950 population of 4,000. The 1950 population of the sub-basin is estimated to be 12,500 and the preliminary release of the 17th Census indicates a small decrease in population since 1940. Seventy-five percent of the population live in the coastal communities of Eastport, Calais and Lubec.

"Agriculture is on a limited scale in the sub-basin because the soil is not well suited to farming, and only about 10 percent of the sub-basin is in farmland. Dairy products are the principal source of farm income which, in 1945, is estimated to have been less than a million dollars.

"The principal source of income in the sub-basin is derived from the canning and processing of seafoods. There is also one sulfite pulp and paper mill. These manufacturing processes are the largest sources of employment and are confined almost entirely to the coastal towns.

"Lumbering is an important activity in the sub-basin with pulpwood being the principal product. The St. Croix Sub-Basin encompasses the greater part of the Grand Lake Stream area and is a famous wildlife region. There has not been much recreational development in the sub-basin because of its proximity to nearby popular seashore resorts."

The 1964 Pollution Control Report of the IJC (International Joint Commission) indicates that this situation is rather stable with the principal industry being the St. Croix Paper Company mill at Woodland, Maine.

The information contained in the Passamaquoddy Fisheries Investigation Report, Appendix IV on the Economics - Canada, indicates that the situation on the other side of the international boundary is pretty much the same:

"It is an area of rolling and forested terrain, with an indented coastline of bays, inlets, estuaries and islands. The landed area has a comparatively thick cover of forest, which provides a resource for a small supplementary industry, although the land itself is not suitable for a prosperous agriculture. Fishing is the principal primary industry.

"The principal concentrations of population in Charlotte County are in the urban centers of St. Stephen, St. Andrews, St. George, and Milltown.... The majority of the people live in rural areas.

"From 1951 to 1956, the most recent intercensal period, the County lost 2.5% of its population, with the main decline in the urban communities of St. Stephen and Milltown."

References

Passamaquoddy Fisheries Investigations. Report to International Joint Commission. October 1959:

a. Appendix I - Oceanography
b. Appendix IV - Economics: Canada

New England Drainage Basins. Federal Security Agency. Public Health Service. Water Pollution Series No. 7. 1951.

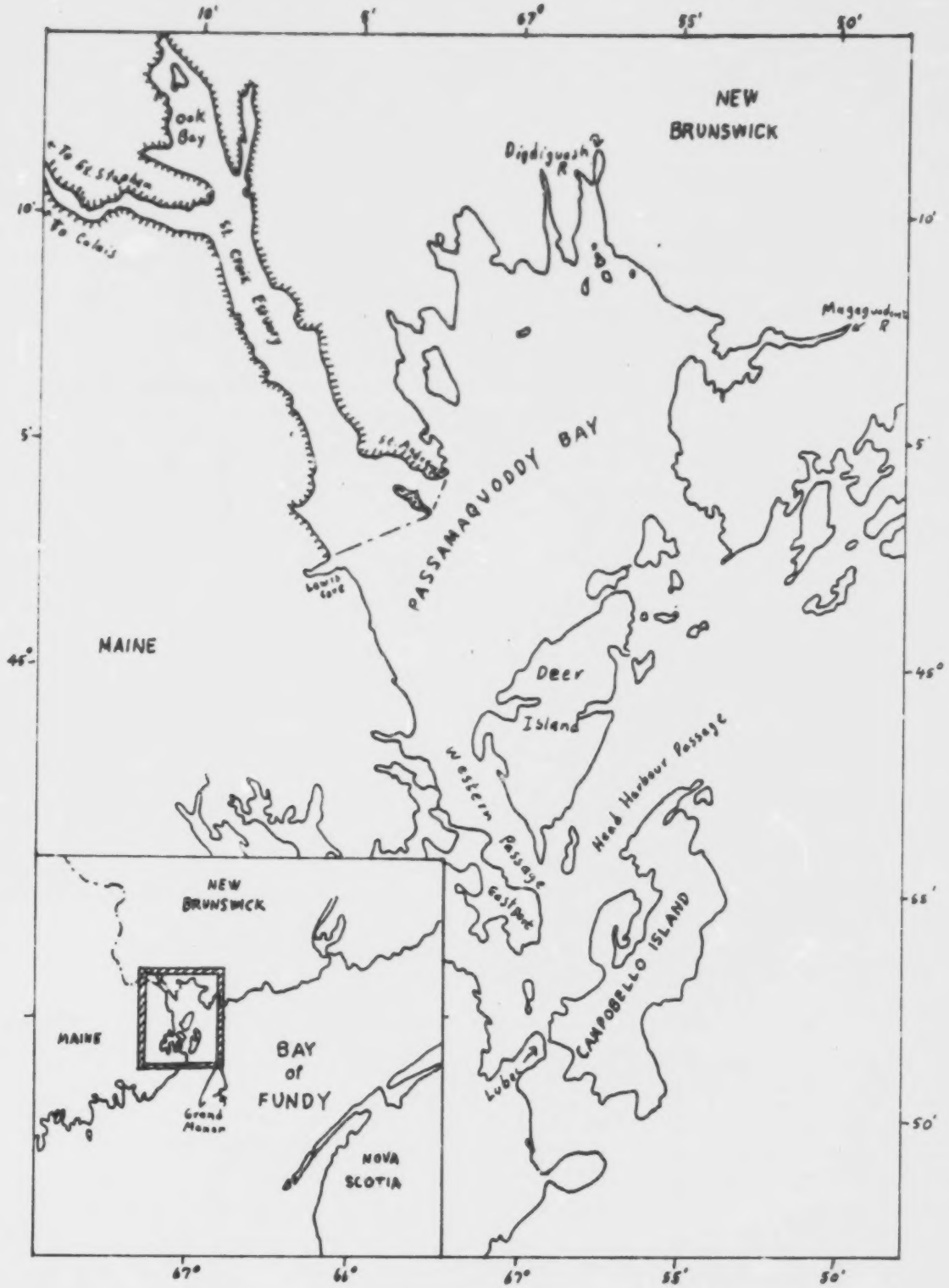
10'
5'
67°
55'
50'
NEW
BRUNSWICK
Oak
Bay
To St Stephen
To Calais
St Croix Estuary
Digdiguash R
Magaguadavic R
PASSAMAQUODDY BAY
Lewis Cove
MAINE
45°
Deer
Island
Western Passage
Head Harbour Passage
Eastport
CAMPOBELLO ISLAND
Lubec
NEW
BRUNSWICK
MAINE
BAY
of
FUNDY
Grand
Manan
NOVA
SCOTIA
67°
66°
67°
55'
50'

Fig I -1

CHAPTER II

SHELLFISH RESOURCES OF THE ST. CROIX ESTUARY

CANADA

The material contained in this summation was obtained from publications on shellfish resources of the Canadian portion of the St. Croix estuary produced by MacPhail, 1949; Medcof, 1956; Medcof, 1962.

Medcof, 1956:

"Soft-Shelled Clams (Mya arenaria)

"There are many hundreds of acres of intertidal flats in the estuary but only 130-150 acres of these are clam-bearing grounds (MacPhail, 1949). The productive areas are centered in the St. Andrews, Johnston Cove, and Oak Bay districts. There never has been any production from the segments of the river marked 0, I and II in Figure 1.

"Clams were regularly fished from the estuary for canning until the late 1940's. The annual production averaged 200,000 pounds (in-shell weight) which today would have a landed value of $12,000.

"With the adoption of the rigid standards of cleanliness required for international trade in raw shucked clam meats, almost all the estuary has been closed to direct marketing and there is no production except by special arrangement with the Department of Fisheries for cleansing before marketing. Recently this has amounted to less than 60,000 pounds (in-shell weight) annually valued at $3,600."

Further on in the paper Dr. Medcof reviews the possible effects of pollution abatement on the fisheries in the estuary.

> "There is no suggestion from the investigations conducted so far that any of the commercially important fish of the estuary are adversely affected biologically by pollution. ... So far as soft-shelled clams are concerned it has been suggested that the fertilizing effects of industrial wastes and domestic sewage on the salt water of the estuary may even enhance development and growth. No careful study has been made of this problem and it must be admitted that herring and soft-shelled clams are not considered to be especially sensitive to conditions that might be deleterious to other organisms."

Although not considered in the Cooperative Program, scallops are included in this summary only as a commercial shellfish inhabiting the estuary.

> "Sea scallops (Placopecten magellanicus) are fished irregularly off Dochet Island (Figure 2) and at intervals of several years, off Devil's Head. The average annual catch is less than 100 pounds of shucked meat valued at $50."

In his conclusions Dr. Medcof made some interesting points concerning pollution and the commercial fisheries.

> "2. Reducing the discharge of raw domestic sewage into the river would probably have no direct effect on any of the present commercial fisheries.
>
> "3. Radically reducing the raw sewage discharge would undoubtedly reduce the counts of faecal coliform bacteria in the water and in the soft-shelled clams in the Oak Bay area and possibly too in the St. Andrew's area."
>
> "5. It is possible that the reduction described in (3) would be great enough to make soft-shelled clams from Oak Bay and St. Andrews fit for direct marketing. But this is not certain because there is considerable land wash and there are other local

sources of contamination in both areas and these would mitigate the effects of reduction in the bacterial loading of the headwaters and might not lend themselves to control at reasonable expense.

"6. The St. Croix estuary fisheries are fairly well known and relatively small. Neighboring estuaries in which pollution is not a serious problem, have small fisheries too. It would appear from this that pollution abatement would not lend to conspicuous improvements in the estuarial fisheries of the St. Croix.

"7. Available information on the nature and amount of pollution entering the estuary and on its dissipation there is extensive. So far as the estuarial fisheries alone are concerned, further field investigations now might be hard to justify. If, however, a particular program of pollution abatement could be justified, wholly or in large measure by likely benefits to other properties of the system, for example, its recreational facilities, then more study of the effects of pollution on estuarial fisheries might also be justified."

Possible effects of the Passamaquoddy Power Project on the St. Croix estuary (High Pool) are described in Medcof, 1962. The High Pool, Low Pool, and Outside are considered. The St. Croix estuary is part of the High Pool and will be affected in a similar manner as the adjacent areas.

"<u>High Pool Prediction</u>

"Figures 2 and 4 show that present clam beds will be permanently submerged and unfishable when the High Pool is formed. These beds will soon die or disappear eventually through sensecence because seed clams do not settle and grow below low-water mark in the Bay of Fundy.

"The new clam zone will be narrow and occupy the steeply sloping landward part (second sub-division, Figure 2) at the flat. We assume that its productive capacity per

unit area will be the same as the present flats. This is to say that production will be reduced in proportion to the reduction in area of flat, i.e., to 5% of present production (Table 1). There are no clams now in what will be the new clam zone. Thus, when the High Pool is created, clam production from Passamaquoddy Bay will cease completely and instantly.

"Most of our marketable clams are 6 to 8 years old (Newcombe, 1935) so the period of no production will be at least 6 to 8 years and probably 10 years because natural stocking of new ground is a gradual process. Indeed, it may be even longer because right now the soil in what will be the new clam zone is too coarse for clams to inhabit. There will too be some resorting of sediments by wave action to produce muddy or sandy soils before clams can begin to populate this part of the flat.

"After 10 years, production may be expected to begin to climb to 106,000 lbs. (5% of present volume) which at today's price will fetch fishermen $5,000 annually (Table 1)."

Concerning scallops Dr. Medcof reports the following concerning High Pool predictions:

"From studies of the Bay of Fundy scallops, Dickie (1955) has concluded that recruitment and population size vary inversely with the rate of water exchange. The reliability of these assumptions and deductions determines the reliability of our predictions for the Quoddy region.

"The water exchange between Passamaquoddy Bay (High Pool) and the Bay of Fundy will be reduced by 50%. Following Dickie, we therefore expect that loss of larvae from the High Pool will be reduced to half and that scallop production will be doubled (Table III). Fishermen's annual earnings should increase by about $12,000."

More detailed information on the condition of the soft clam flats on the Canadian side of the St. Croix estuary is available in the survey report of MacPhail (1949). This survey was conducted in April and May, 1947, on the entire shoreline area of Charlotte County, New Brunswick. The St. Croix estuary is located within this area.

The nature of MacPhail's survey was to evaluate various aspects of the flats and the clams, such as nature of the soil, water circulation over the flats, size composition of the clam populations, and the past, present, and potential productivity. No attempt was made to determine the standing crop of soft clams on any flat.

A summary of the St. Andrews, Oak Bay and Waweig River regions follows:

St. Andrews (Figure 5)

#9 Quinn Weir

(a) 3/4 to 1 mile long
(b) poor recruitment, few clams
(c) rocky soil, little fished

#10 Dump Flat

(a) 3 acres
(b) fair recruitment, fair quantities
(c) rocky, clay sub-soil, little fished

#11 Park Flat

(a) 10 to 15 acres
(b) fair recruitment and size distribution
(c) mud - sand, fair to good quantities

#12 Lighthouse Flat

(a) 4 to 5 acres
(b) fair recruitment and size distribution
(c) sand, gravel and small rock, fair quantities

#13 C.P.R. Wharf to Public Wharf

(a) 6 to 8 acres
(b) fair recruitment and size distribution
(c) sand - mud, some soft mud, fair quantities

#14 Public Wharf to Niger Reef

(a) 10 to 15 acres
(b) fair recruitment to size distribution
(c) sand - mud, rocky, fair quantities

#15 Pottery Bridge Flat

(a) 15 acres
(b) fair recruitment and distribution
(c) sand - mud, soft mud, good quantities

#16 Navy Island

(a) data unavailable

Oak Bay (Figure 6)

#1 and #2 Todd's Pt. - Bedford Cove

(a) 1 to 1¼ miles long
(b) fair recruitment, clams stunted
(c) sand - mud, rock, ledge, fair quantities

#3 Little Island

(a) 2 to 3 acres
(b) fair recruitment and size distribution
(c) gravelly soil, fair quantities

#4 Big Island

(a) 50 to 60 acres
(b) fair recruitment and size distribution, slow growth
(c) sand - mud, occasional ledge, good quantities

#5 McCubrey's Beach

(a) 6 to 8 acres
(b) fair recruitment and size distribution, slow growth
(c) sand - mud, ledge, rock, fair quantities

#6 Gilman's Beach

(a) 2 to 3 acres
(b) fair recruitment and size distribution, fair growth
(c) sand, rock and ledge, fair quantities

#7 Hills Point

(a) 7 acres
(b) fair recruitment and size distribution, slow growth
(c) sand - mud, rocky areas, good quantities

Waweig River (Figure 6)

#8 Waweig River

(a) 1 to 2 miles long
(b) poor recruitment, slow growth
(c) sand - mud, poor quality flat

From this survey it becomes apparent that clam production was located in two rather distinct areas of the St. Croix estuary -- Oak Bay and St. Andrews. The area between the mouth of the Waweig River and Joe's Point was devoid of any appreciable soft-clam production.

Summary

Estimates on the density and distribution of soft-shelled clams on the shores of the Canadian side of the St. Croix estuary since the early 1950's is unavailable. The combination of a downward trend in quantities of shellfish during this general period and the curtailment of harvesting resulting from rigid water quality standards has been the probable cause for any generation of sustained interest in the clam resources of the estuary. Efforts were made to utilize some stocks from restricted flats through a process of transfer and natural cleansing, but these too were rather localized and limited.

A general statement on the soft clam fishery of the estuary is that it was small to begin with, and if the area were rehabilitated the scope of the fishery would remain small.

Changes stemming from the proposed Passamaquoddy Power Project on the soft clam resources of the St. Croix would be such that a period of at least 10 years would be needed to rejuvinate the fishery.

UNITED STATES

The following remarks are extracted from an undated (probably 1956) report on the Commercial Fisheries of the St. Croix estuary published by the State of Maine Department of Sea and Shore Fisheries:

Soft Shell Clam (Mya arenaria)

> "The soft-shell clam fishery is the second most important fishing activity of the estuary both in volume and in value. During the period, annual production averaged fifty thousand pounds valued at fourteen thousand dollars."

This estimate is based on the shoreline from Calais to Estes Head, Eastport. The area under consideration in this report includes the shoreline from Calais to just north of Lewis Cove in Perry. This area then is approximately half the area from Calais to Estes Head and therefore it will be assumed that the production figures will be halved (see Table 1 - Maine Landings - St. Croix Estuary).

"Intensive digging during the 1949-1952 period together with increasing green crab predation have greatly reduced the available abundance of this species.... In view of current shellfishing activity in these areas, it can be anticipated that clam abundance supported by scattered survivors of recent year classes will remain at approximately the same level as that which during 1955 and 1956 produced an annual average of twenty-two thousand pounds of clams."

For that part of the estuary under consideration in this report, a production figure of eleven thousand pounds of clams will be assumed for 1955 and 1956.

Scallop (Placopecten magellanicus)

It is assumed that sea scallop production is approximately the same on both sides of the international border. According to Medcof (1956):

"Sea scallops (Placopecten magellanicus) are fished irregularly off Dochet Island and at intervals of several years, off Devil's Head. The average annual catch is less than 100 pounds of shucked meat valued at $50."

Soft Clam Producing Areas

The production estimates and condition of producing areas are taken from 1956 survey reports furnished by the State of Maine Department of Sea and Shore Fisheries. (Figure 7)

"According to my information (M. Richards, 1956), there are no regular commercially producing areas at the present time along the U. S. shore of the St. Croix River from Eastport to Calais. Production stopped generally about 1951-52 in this section and not much has been done since.....

"Major clam producing areas in the past were: Gleason Cove, Lewis Cove, Mill Cove and Brooks Cove. Smaller areas which formerly had some production on a commercial scale were: north end of Moose Island, SE and NE sides of Carlow Island, Pleasant Point and Frost Island Ledges, inside bar at Little River, Liberty Point, Lamb Cove, Wilson Cove, and Dochet Island and bar. ....

"Some digging has been reported just above Devils Head and on the flats and reef below Quarantine (Elliott Flats). There is some disagreement as to the quantity and quality of clams this far up the river. No clams reported above Quarantine; reason given was too much sawdust and refuse.

"1. Mill Cove - June 1956

"About 1938 there were 35-40 diggers working this cove with the good diggers averaging 5 bushels a tide. Evidence of a little digging here and there on the exposed flats (1956). No commercial digging.

"2. Liberty Point - June 1956

"The small cove just north of Liberty Point was good in the past.

"3. Brooks Cove - June 1956

"The flats are sand and gravel with some clay; the sand is uneven as though it might shift at time. .... Evidence of a little digging here and there. .... North of the cove there is about 250' of exposed area between tides of which an estimated one-fourth could not be dug because of boulders and ledge."

It appears that 1951 was the last productive year for Brooks Cove.

"4. Lamb Cove - June 1956

"..... suggested that Brooks and Mill Coves in Robbinston should be closed, and Lewis Cove in Perry; but not Lamb Cove, nor Wilson Cove in Red Beach, as there is nothing in either now.

"5. Little Dochet Is. - June 1956

"..... also dug around Dochet Island and the bar.

"6. Lowe Cove - June 1956

"The bar at Lamb Cove in Robbinston also formerly produced clams, but there were none to amount to anything in the small cove above (Lowe Cove). .... two diggers may have taken 100 bushels out one winter.

"7. Red Beach Cove - June 1956

"..... said that he stopped digging commercially about the spring of 1952 as the clams became so scarce that he could not make a living at it.

"8. Wilson Cove - June 1956

"....suggested that Brooks and Mill Coves in Robbinston should be closed, and Lewis Cove in Perry; but not Lamb Cove, nor Wilson Cove in Red Beach, as there is nothing in either now.

"9, 10, 11. Devils Head, Miller Pt., Quarantine (Elliot Flats)

"Some digging has been reported just above Devils Head and on the flats below Quarantine (Elliot Flats). There is some disagreement as to the quantity and quality of clams this far up the river. No clams reported above Quarantine; reason given was too much sawdust and refuse."

Summary

Information on the condition of the shellfish resources since 1956 is lacking. Prior reports indicate that there has been a definite downward trend in production in the estuary with a general stoppage of commercial activity occurring in 1951-52. Of the several coves and bars reviewed in the 1956 report only two, Mill Cove and Brooks Cove, possess quantities capable of supporting "mess digging" for home consumption.

This depleted state of the soft-clam fishery may, however, have been corrected over the past several years because of the prevention of harvesting due to the quality of the water. With the exploitation factor removed, as well as a general curtailment of green crab activity, natural recruitment into the fishery may have been such that there now exists substantial quantities of soft clams. To date no reports or publications of resource surveys exist to verify an abundance or lack of soft clams in the estuary.

Recommendations

Considering the conclusions reached by Medcof (1956) concerning the soft-shell clam fishery of the St. Croix estuary it may be safely assumed that the resource is relatively small compared to other clam producing areas in the United States and Canada.

With this thought in mind two questions may be asked concerning the present status of this clam resource (1) for the purpose of ascertaining whether or not any significant changes have occurred over the last several years, or (2) to obtain precise information on actual amounts of resource presently inhabiting the producing areas. Recommendations are advanced for investigating these objectives.

(1) What, if any, changes have occurred since the last soft clam resource surveys?

It is recommended that a one to two week "spot check" type survey be made of known major soft clam producing areas on both sides of the estuary for the purpose of obtaining a

general impression of the condition of the fishery. Items for consideration would be size distribution, condition of the meats, recruitment and bottom sediments.

To complete this type of coverage in the time allotted would require two (2) men and the necessary floating equipment from the Northeast Research Center and equal assistance from Maine and Canadian fisheries personnel when in the respective area.

(2) Is the area capable of supporting a commercial soft clam fishery?

It is recommended that a three to four week soft clam resource survey be conducted to obtain more precise information on the density-distribution patterns of clams in the known producing areas. The purpose of this survey would be to determine not only the standing crop of clams available but also size distribution, condition of the meats, recruitment into the fishery and bottom sediments.

Suitable assistance to conduct this survey would be required from Maine and Canadian fisheries personnel. The services of two (2) men and necessary floating equipment would be supplied from the Northeast Research Center.

References

1. Dickie, L. M. 1955. Fluctuations in abundance of the giant scallop, Placopecten magellanicus (Gmelin), in the Digby area of the Bay of Fundy. J. Fish. Res. Bd. Canada, 12(6):797-857.

2. Fisheries Statistics of Canada 1937-1963. Department of Fisheries, Dominion Bureau of Statistics, Economics Branch.

3. MacPhail, J. S. 1949. Survey of Clam Flats - Charlotte County. N.B. Fish. Res. Bd. Canada, Original Manuscript No. 748, p.1-62.

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5. Medcof, J. C. 1962. Possible Effects of Passamaquoddy Power Project on Clams, Scallops and Shipworms in Canadian Waters. Bull. Fish. Res. Bd. Canada, No. 33, 877-889.

6. Medcof, J. C. 1956. Appendix 3, Pollution and the Fisheries of the St. Croix Estuary. Pollution Survey Report of Pollution Sub-Committee St. Croix River Reference, International Joint Commission, December 1956.

7. Newcombe, C. L. 1935. Growth of Mya arenaria L. in the Bay of Fundy Region. Canadian J. Res., D, 13:97-137.

8. Richards, M. E. 1956. Notes on Shellfish Survey of the St. Croix Estuary. Maine Department of Sea and Shore Fisheries.

NOTE: Re the group of figures and tables following Chapter II, Figure 3 has been omitted.

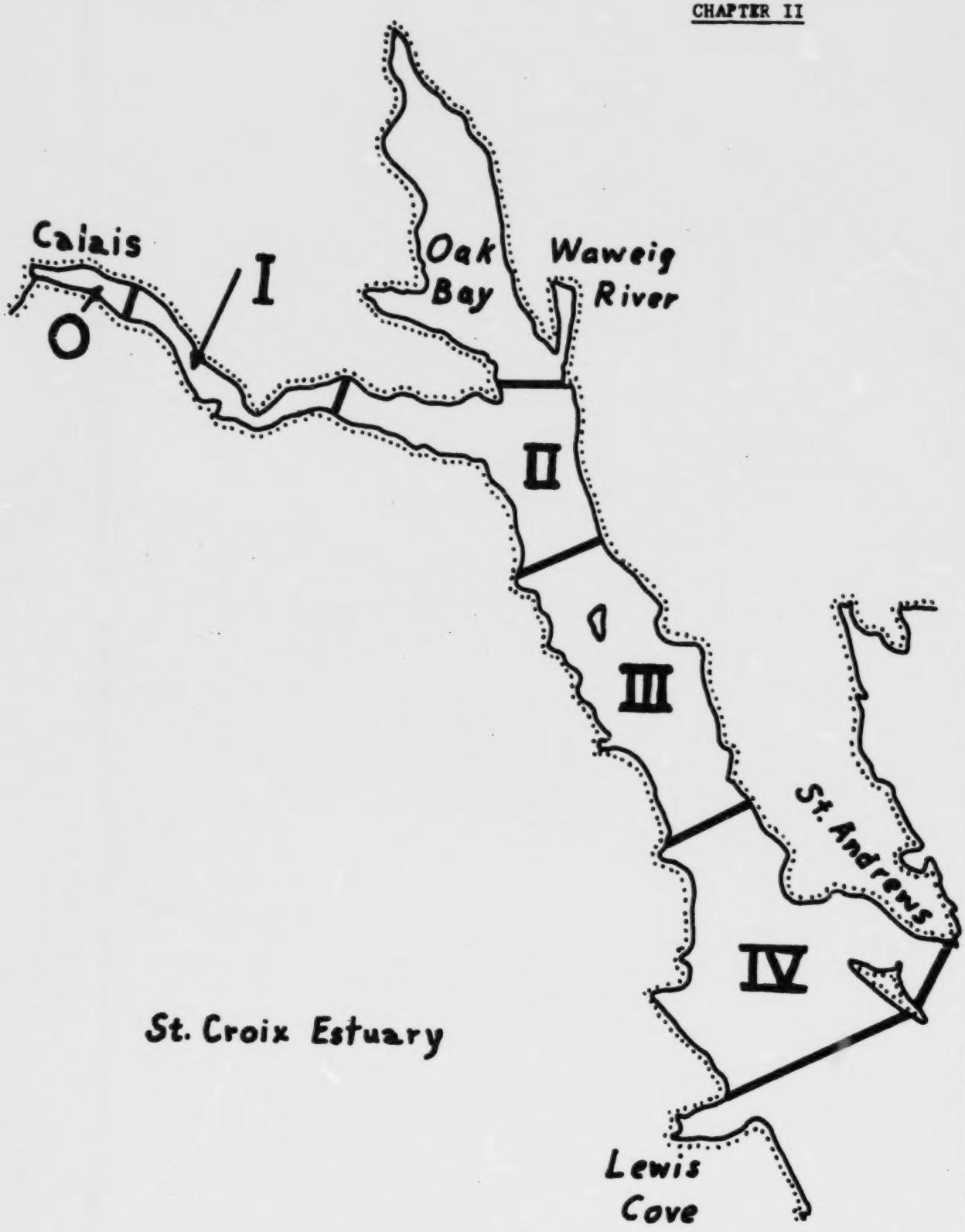

Calais
I
Oak Bay
Waweig River
II
III
St. Andrews
IV
St. Croix Estuary
Lewis Cove

FIGURE 1

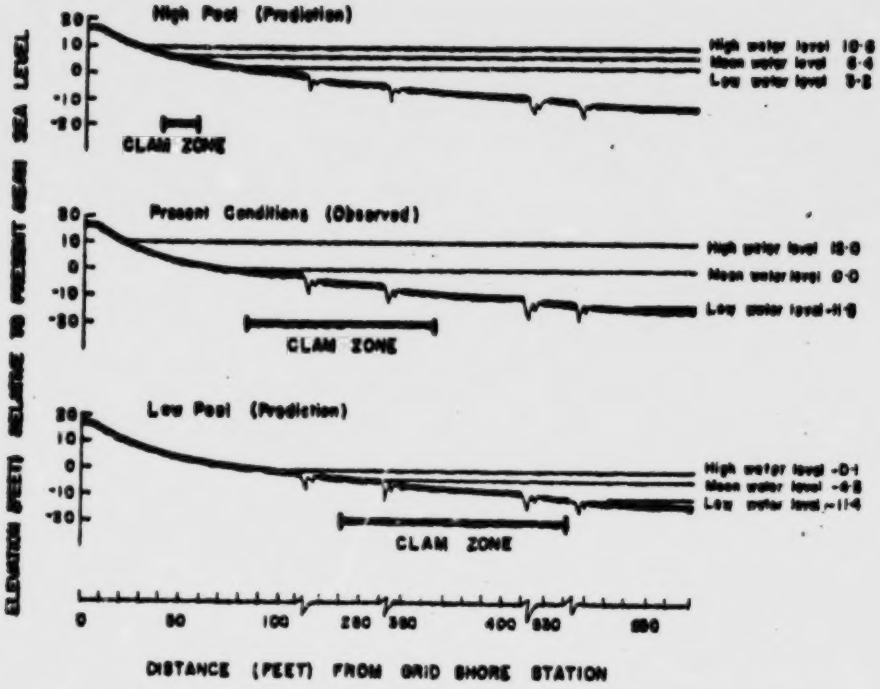


FIG. 2. Profile of a typical flat (St. Andrews habour) showing present and predicted positions of clam beds in High and Low Pools in relation to mean sea level and to highest high and lowest low water levels.

CHAPTER II

Medcof, 1962

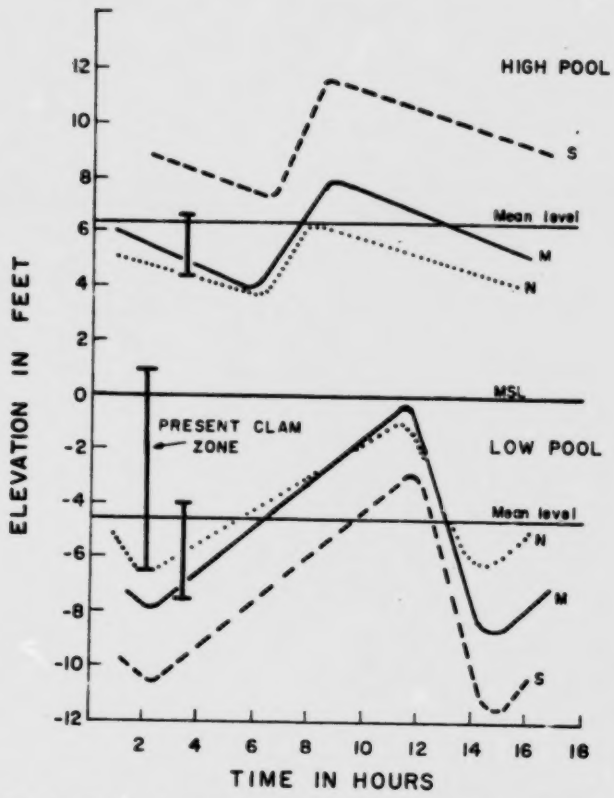


FIG. 4. Predicted vertical positions and extents of clam zones (vertical bars) in High and Low Pools in rela.ion to mean sea level and to predicted water levels when the tide is in its neap, mean and spring phases. The position of the present clam zone, as in Figure 3, is shown here for comparison with the new positions (after Trites 1961).

CHAPTER II

Medcof, 1962

TABLE I. Present (mean for 1937 to 1955 inclusive) and predicted annual landings and landed values of soft-shell clams from various Canadian parts of the Quoddy region of the Bay of Fundy.

Area	Present			Predicted				
	High pool	Low pool	Outside	High pool		Low pool		Outside
				1st 10 years	Thereafter	1st 10 years	Thereafter	
Deer Island								
Pounds	52,300	0	0	0	2,600	0	0	0
Dollars	845	0	0	0	130	0	0	0
Campobello Island								
Pounds	0	17,300	8,700	0	103,000	9,000	19,000	8,700
Dollars	0	285	140	0	5,115	450	950	140
Mainland bordering Passamaquoddy Bay								
Pounds	2,063,000	0	0	0	103,000	0	0	0
Dollars	44,520	0	0	0	5,115	0	0	0
Mainland Outside								
Pounds	0	0	1,945,000	0	0	0	0	1,945,000
Dollars	0	0	45,100	0	0	0	0	97,685
Totals by areas								
Pounds	2,115,300	17,300	1,953,700	0	106,000	9,000	19,000	1,953,700
Dollars	45,365	285	45,240	0	5,300	450	950	98,000

	Present	Predicted	
		1st 10 years	Thereafter
Grand totals for Quoddy region			
Pounds	4,086,300	1,962,700	2,078,700
Value*	$204,315	$98,500	$103,950

*Based on the current price of 5 cents per pound. The 19-year average value is $90,890.

CHAPTER II

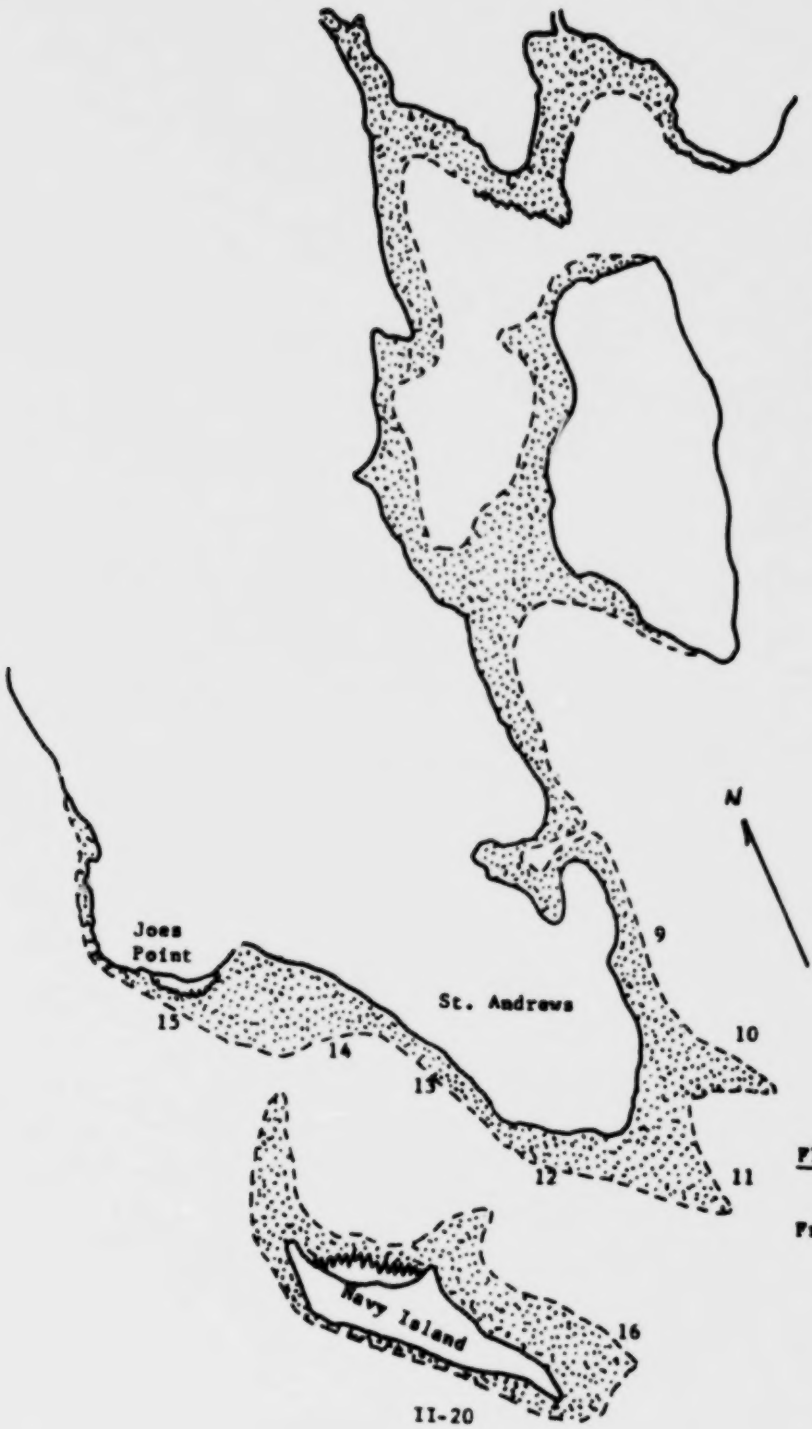
Medcof, 1962

TABLE III. Present (mean 1937–1955) and predicted annual landings (pounds of meat) and landed values of scallops for various Canadian parts of the Quoddy region.

Statistical district no.	Present			Predicted		
	High pool	Low pool	Outside	High pool	Low pool	Outside
51						
Deer Island						
Pounds	7,300	0	7,300	14,600	0	7,300
Dollars	2,770	0	2,770	5,840	0	2,920
Campobello Island						
Pounds	0	0	7,300	0	0	7,300
Dollars	0	0	2,770	0	0	2,920
52						
Pounds	21,900	0	0	43,800	0	0
Dollars	8,910	0	0	17,520	0	0
53						
Pounds	0	0	16,000	0	0	16,000
Dollars	0	0	7,240	0	0	6,400
Totals by areas						
Pounds	29,200	0	30,600	58,400	0	30,600
Dollars	11,680	0	12,780	23,360	0	12,240
Totals for Quoddy region		*Present*			*Predicted*	
Pounds (19-year av.)		59,800			89,000	
Dollars (current value 40c lb)		23,920			35,600	

CHAPTER II

Medcof, 1962



ST. ANDREWS

9. Quidn Weir
10. Dump flat
11. Park flat
12. Lighthouse flat
13. C.P.R. Wharf to Public Wharf
14. Public Wharf to Niger Reef
15. Pottery Bridge flat
16. Navy Island

FIGURE 5

From MacPhail, 1949

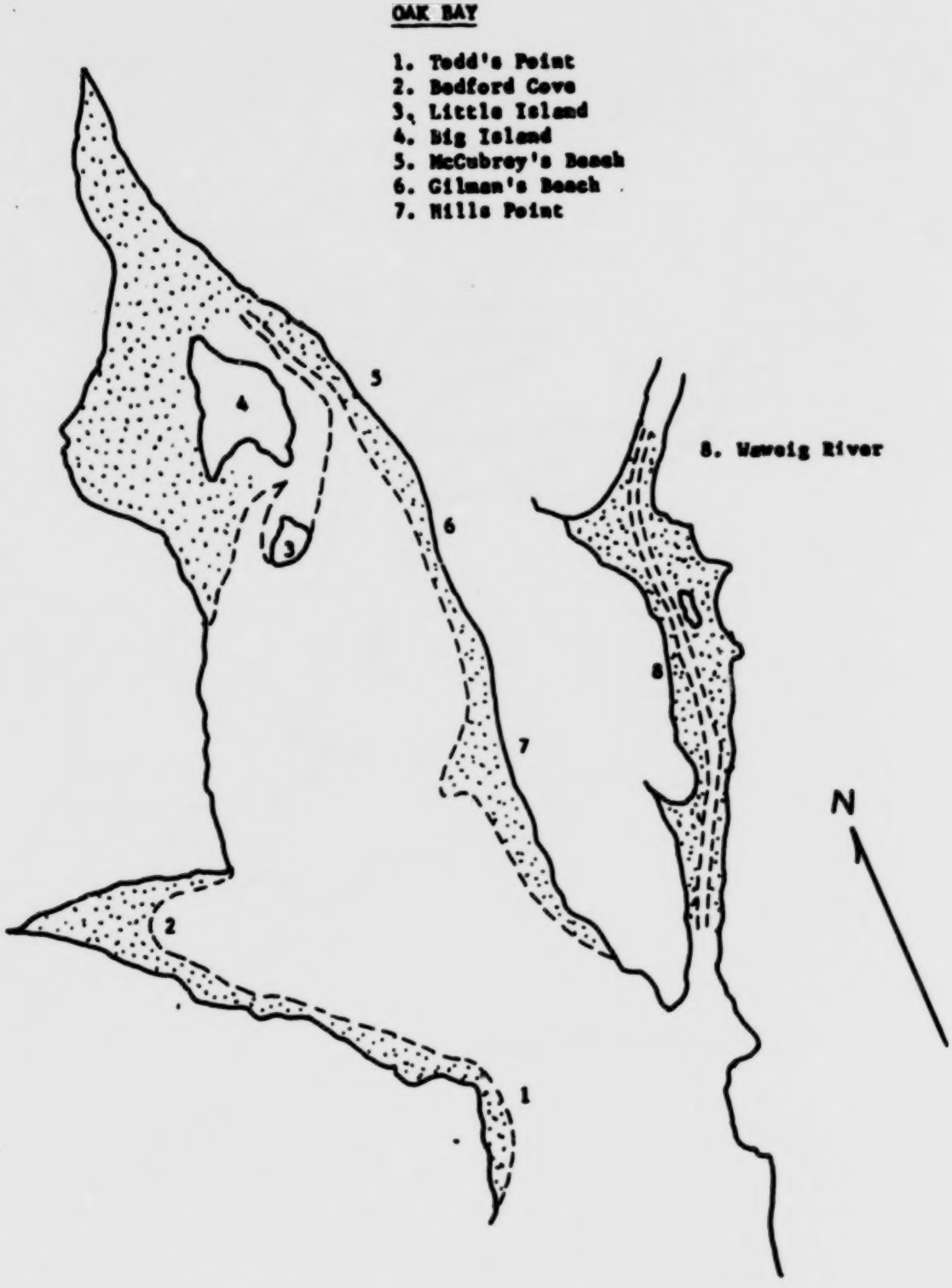


FIGURE 6

From MacPhail, 1949

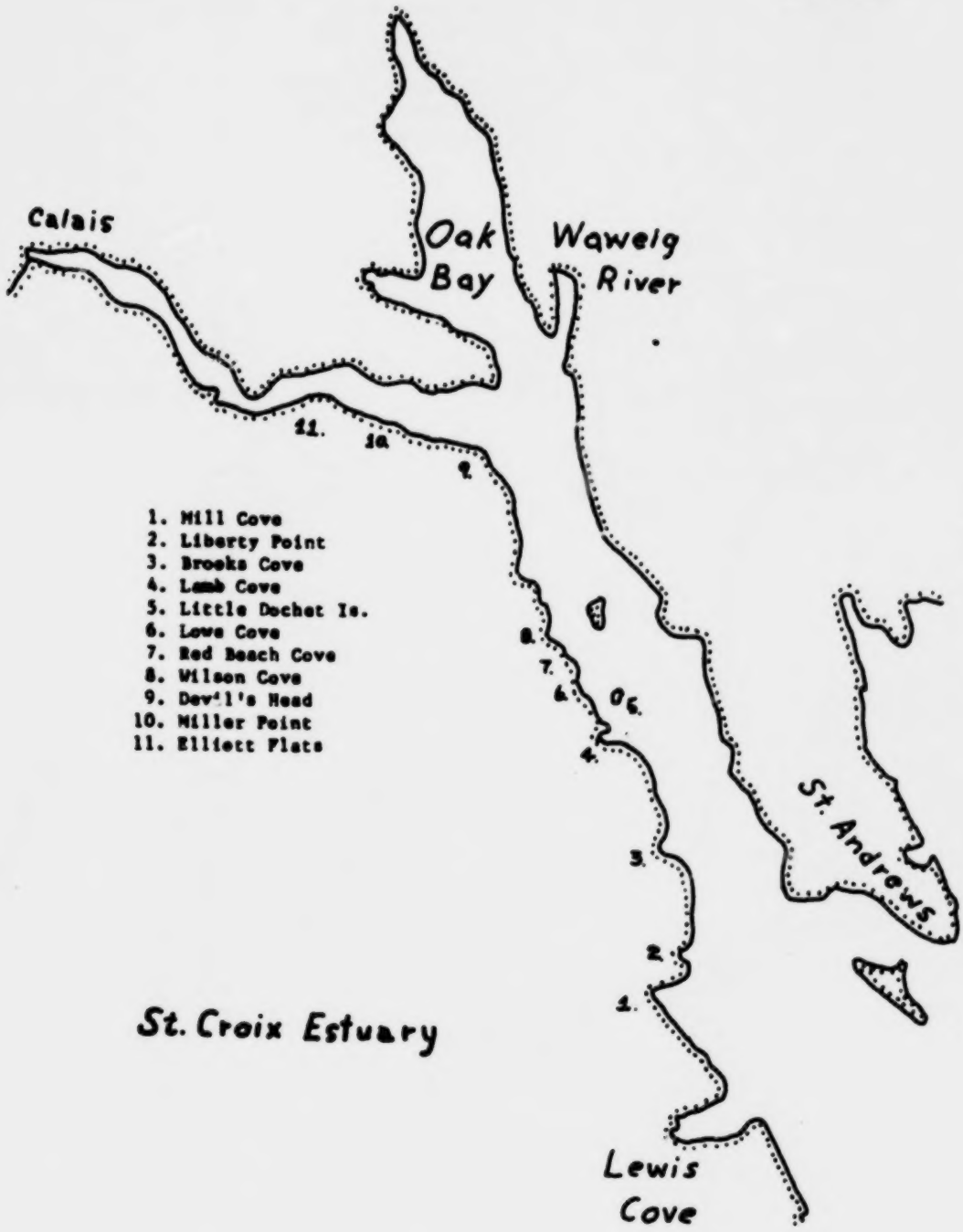

Calais
Oak Bay
Wawelg River
St. Andrews
St. Croix Estuary
Lewis Cove
1. Mill Cove
2. Liberty Point
3. Brooks Cove
4. Lamb Cove
5. Little Dochet Is.
6. Lowe Cove
7. Red Beach Cove
8. Wilson Cove
9. Dev'l's Head
10. Miller Point
11. Elliott Flats

FIGURE 7

TABLE 1. MAINE LANDINGS - ST. CROIX ESTUARY

	1951		1952		1953		1954		1955		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
CLAMS												
*	113,400	26,195	72,248	21,169	25,043	8,339	17,550	6,406	21,938	7,920	250,179	70,029
**	56,700	13,098	36,124	10,584	12,521	4,169	8,775	3,203	10,969	3,960	125,089	35,014

5-YEAR AVERAGE		
	Pounds	Value
CLAMS		
*	50,036	14,009
**	25,018	7,004

*Calais to Estes Head, Eastport
**Mill Cove, Robbinston to Calais

CHAPTER III

HYDROGRAPHY OF THE ST. CROIX ESTUARY

Summary

The most relevant hydrographic data presently available are those of Ketchum and Keen (1953), and those in the Report to IJC, Appendix One: Oceanography (International Passamaquoddy Fisheries Board, 1959). Most of the available information is more than eight years old; most is for the late summer months and none covers a time span of more than three consecutive months. Synoptic data on the St. Croix covering a full year are apparently nonexistent, although such data for other parts of the Quoddy region are reportedly gathered by the Biological Station at St. Andrews. Data provided by the U. S. Geological Survey (Meade, 1966) show that surface salinities throughout the St. Croix estuary differ little between high and low tides, indicating the waters to be well mixed. Salinities at St. Andrews are of the order of 30 o/oo; at Devil's Head, near the entrance to Oak Bay, 20-25 o/oo; at Whitlock's Mills Light, about halfway between Calais and Devil's Head, 14-25 o/oo (differences in salinity between high and low tides appear to be greatest in this vicinity); and at Calais, 0-5 o/oo.

Flushing in the St. Croix has been calculated according to the method of Ketchum by Ketchum and Keen (1953) and by Forgeron (in International Passamaquoddy Fisheries Board, 1959). The flushing time, defined as the average time required for one day's accumulation of river water to pass from the estuary (at St. Andrews), was calculated by Ketchum and Keen to be about eight days, and by Forgeron to be from 5.7 to 6.8 days depending upon time of year (probably reflecting St. Croix river discharge variations) and choice of base salinity. Flushing time calculated by the method of Ketchum will vary somewhat with changes in tidal range and especially changes in river discharge, so that the flushing time will be shorter for maximum tidal ranges and maximum river discharges, and vice versa. The calculations cited above, based as they both were upon conditions prevailing in late summer when river discharges as a rule will be minimal, should represent maximum flushing times.

Direct information on travel times and current velocities in the St. Croix is lacking, at least from sources in the U. S.

Recommendations

Flushing calculations available are adequate, and no need is seen for pursuing this line of investigation any further. Information on travel times in the upper St. Croix would probably be desirable, although the necessity for such information would be dictated by the magnitude and character of the pollution sources on the upper estuary.

Data on seasonal variation of such parameters as salinity, temperature, and turbidity are probably of more value academically than practically, so a year-long study of these variables is probably not worthwhile at this time. Data on annual variation in dissolved oxygen would be of value, but gathering this data should properly by the job of the IJC.

References

International Passamaquoddy Fisheries Board, 1959, Passamaquoddy Fisheries Investigations - Report to International Joint Commission, Appendix I: Oceanography. International Joint Commission, Ottawa, Ontario. D.O.C. and Washington, D.C., U.S.A. viii and 7 chapters, separately paginated.

Ketchum, B. H. and D. J. Keen, 1953. The exchanges of fresh and salt waters in the Bay of Fundy and in Passamaquoddy Bay. J. Fish. Res. Bd. Can., 10(3). pp.97-124.

Meade, R. H. 1966. Personal communication.

CHAPTER IV

POLLUTION SOURCE -- BACTERIOLOGICAL SURVEY

AND

ANALYSIS OF EFFECT ON SHELLFISH SANITATION

It is known from available references that considerably more information exists in reports which were not obtainable for this present review. Apparently the 1962 IJC (International Joint Commission) Pollution Control Advisory Board report contained detailed information regarding the pollution sources on the St. Croix River. Likewise, there is report of prior river studies for the years 1956, 1959, and 1962, which have not been available for use in this special request analysis.

Although it might have been desirable to have all the information for review, the data that is available appear to provide sufficient information with which to answer the questions raised in the request memorandum.

For a chart of the area of interest and the area of study, reference should be made to Figure I-1 in Chapter I and to Figure IV-1 of this chapter.

Pollution Sources (See Figures IV-1, IV-2 and IV-3.)

The primary sources of pollution as listed in the 1964 report are as follows:

State of Maine	Population	Population Served by System
Woodland	1,393	
Milltown		
Calais	4,223	3,800 est.
Province of New Brunswick		
McAdam		
Milltown	1,892	
St. Stephen	3,380	

The above communities were listed in the report, but the population data were obtained from a highway map for 1960-61. The estimate of the population served is from the 1962 Inventory of "Municipal Waste Facilities." Since the 1964 IJC report apparently was primarily interested in the pollution in the fresh water portion of the river and its effect on the river and the estuary, no mention is made of other pollution sources along the estuary. One such source that might have to be taken into account when considering the use of the receiving waters for shellfish markets is that of St. Andrews at the lower end of the estuary. The following information was provided by letter from the Public Health Engineering Division of the Canadian Department of National Health and Welfare:

> "In the St. Andrews area (pop. 1,500) domestic sewage is the primary source of pollution. A collector system serving the town discharges untreated sewage to the adjacent waters through several outfalls."

In the matter of industrial pollution, the 1964 IJC report indicated that "the Georgia-Pacific Corporation (St. Croix Paper Company) mill in Woodland, Maine, continued to represent the major source of industrial pollutants contributed to the St. Croix River." Again, because of an apparent stopping of pollution interest for IJC at the head of tide water, it is not absolutely known whether or not there may be other sources in the Canadian portion of the estuary (particularly Oak Bay). From personal observation in recent years no obvious major sources are known to exist.

An excellent source of information regarding pollution sources in the United States portion is the 1954 series of reports prepared by the Maine Water Improvement Commission. The following quotations and the material presented in Figures IV-2 and IV-3 are from that report series:

"Three significant sources of pollution degrade the St. Croix throughout its lower reaches. The lone significant source of industrial waste is from a paper mill in Woodland, with a number of sawmills contributing a relatively unimportant quantity. Sanitary wastes pollute the waters from private sewers, serving about two hundred people, in the town of Princeton, and from twelve hundred persons through public sewers at the village of Woodland. There are also small quantities of sewage entering at Vanceboro, Baring, and possibly other points, while at Calais there are at least 4000 persons tributary to sewers entering the river, although some enter below head of tide."

The same report does give some information relative to the pollution sources existing on the Canadian side in the following statement:

"In the report above the St. Croix River has been considered only as a problem of the State of Maine and to all practical purposes the study of pollution of the fresh water portion of this stream is not altered when it is considered in its entirety, as it should be as an international stream. Canadian pollution is not a significant factor until the town of St. Stephen, N.B., and its vicinity are reached, then within a very short distance from tidewater the sewage from at least five thousand persons plus waste from a textile mill and other industries, while the effect of this waste is apparent in only a very short segment of the fresh water it has a profound effect on the tidewater portion of the estuary."

Stream Hydrography and Related Meteorology

In the search for relationships with pollution loading conditions it is desirable to study the stream discharge characteristics and, in turn, the relationships to precipitation. Given in Figure IV-4 is the 34-year average discharge for the St. Croix as contained in the Oceanography appendix to the Passamaquoddy Fisheries Investigations report of 1959. The 1963 data are taken from the Surface Water Records of Maine for that year. Also included is the Annual Summary data for precipitation as provided by reports of the Weather Bureau. It is worth noting that during the August 1963 survey period both the average run-off and precipitation were almost coincident with the long term averages for the same period of the year.

The daily records of interest for the period of survey are given in Figure IV-5. This record highlights one fact in river flow that is of special interest here, and that is the extremes in river control for power generation and other uses. This is indicated by the low flow shown for Sunday, 12 August, for the Baileyville station and the apparent turning off of the water at Grand Lake just after that time.

A review of the entire precipitation picture in the watershed and estuary area is given in Figure IV-6 as is the maximum and minimum temperature record.

Bacteriological Survey

The following three manuscript reports have been made available by the Canadian Department of National Health and Welfare.

No. 63-1 A Bacteriological Study of the St. Croix River and Estuary, Conducted for the Advisory Board on Water Pollution, St. Croix River, International Joint Commission.

No. 63-1A Additional Coliform Test Data, St. Croix River Bacteriological Study, 1963. Conducted for the Advisory Board on Water Pollution International Joint Commission.

No. 63-2 A Bacteriological Study of Oak Bay, N.B. Shellfish Area N.B. 43.

As indicated by the title the first two were conducted as part of the "Data Supplement" for that April 1964 report of the IJC. Of interest to this review are the some 888 MF tests conducted on samples from 68 stations located on 18 separate ranges. In addition, at one station in each range a MPN and EC(+) was run for a total of 232 of each.

Analysis of Effect on Shellfish Sanitation

> "The coliform median MPN of the water does not exceed 70 per 100 ml, and not more than 10 percent of the samples ordinarily exceed an MPN of 230 per 100ml for a 5-tube decimal dilution test .... in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions."

In the St. Croix estuary area it is this requirement that will govern any area analysis related to shellfish sanitation purposes. As indicated by the findings reported on in Chapter II, it is the Oak Bay area that would be expected to govern any concern for a water quality improvement program. Thus the following analysis of the available information is aimed at determining what type of water quality improvement program would be needed and where, in order to permit the use of the Oak Bay area for marketable shellfish resource purposes.

> "The foregoing limits need not be applied if it can be shown by detailed study that the coliforms are not of direct fecal origin and do not indicate a public health hazard."

A review of the IJC report and the survey data indicates that any analysis of this situation leads one immediately to the two most difficult questions facing a person utilizing the above quoted standards, namely:

1. What does the indicator indicate? Which one to use?

2. What are the most unfavorable hydrographic and pollution conditions?

(Indicator Considerations)

For the purpose of this analysis a log probability plot was prepared of the data for the one station on each range in the tidal area (Range #7 on) for which MF (Membrane Filter), MPN (Coliform) and EC (EC gas positive) tests were run for each day of the study. These plots are contained in the Appendix to this report. Next a plot was made of the relationship of the MF and MPN values against the EC values for the 50% values from the log probability plot. A similar plot was made for the 10% values and the 90% values. These are contained in the appendix. The three separate plots appeared to be in good agreement except that the 90% value plot showed considerable variation. The "eye-fit" line for the 50% values is shown in Figure IV-7. Also shown on that figure is a plot for the 10%, 50% and 90% data for other areas in Canada as contained in the 1961 Workshop reports and a comparison of the 1962 and 1963 median values for river ranges from the IJC report.

Now comes the part for personal judgment. In the fresh water portion the information indicates that between 1962 and 1963 the EC indicated stable conditions which is in keeping with the pollution source findings, while the MF and MPN showed considerable variation from station to station. Certainly the EC test appears to be the better indicator of conditions in the fresh water portion than either of the other tests.

In the case of the tidal area (Range #7 on) the data for the two years appear in good agreement. Even more significant is the fact that the MF vs EC and MPN vs EC data give a good "eye-fit" line of relationship throughout the entire tidal area and range of values.

It is noted that the MF values are consistently higher than the MPN values for a given EC level. Both of these are in turn higher than similar relationships for other areas in Canada which still further indicate considerable variation between different areas. The question naturally arises, in keeping with the second quotation from the manual above, as to what indicator should be used and at what level since that quotation indicates that other than the stated standard may be used in some situations.

In the tidal areas the relationships between the three indicators appear to be consistent and uniform -- the MF and MPN being about ten times the EC value at all ranges. The difference in levels is consistent with the supplementary standard adopted at the 1961 Workshop wherein a value of 7.8 EC was considered comparable with the present 70 value. Accordingly since the majority of the samples were analyzed by the MF technique it is this indicator method that is considered applicable at the stated level of 70 per 100ml. There is no indication or justification for utilizing a lower value in the estuary. If the EC were to be used it would have to be used at one-tenth the MF value and would indicate the same thing. Since there are fewer EC tests made during this survey it is not the method of choice for studying the other equally important relationships.

(Most Unfavorable Conditions)

In terms of the pollution condition all sources are discharged raw to the river system. Since the sewer systems are also reported to be combined sewer systems it would appear that the search for the most unfavorable situation would be related to storage time in the sewers before discharge and any flushing out effect. Both of these in turn would be related to rainfall.

The second condition to be considered is the amount of fresh water that may be available for dilution of the discharged sewage. This may be related to the rainfall and winter storage situation resulting from snowfall.

The third condition that might be suspected is that of tidal range which would influence the travel times of pollution from source to area of consideration.

There is ample data available for the survey period for the rainfall, stream flow and MF data for ranges and stations. There is some information indicating the location of pollution sources with reference to sampling ranges. There is no direct information bearing on the relationship of the quality and quantity of sewage discharge in relation to rainfall and little information, except tide elevation prediction, having a bearing on dilution and travel times in the estuary. Accordingly heavy reliance is made upon the picture as revealed by the bacteriological study.

As stated previously the bacteriological samples were collected during a time when both precipitation and run-off were normal for the period of the year. However, as indicated in Figure IV-5 there is considerable daily variation in flow due to storage controls in the river system. Accordingly it would be absolutely necessary to consider river flow information when analyzing the bacteriological results from the fresh water portion of the river. The complexity of this situation is further shown by the situation where at a time when the volume was halved at Grand Lake the flow at Baileyville was double the previous stable values.

A plot of the daily MF values for the arithmetic mean of the station results for a given range is made for all ranges and is shown in the series of Figures IV-8 thru IV-17. The location of the ranges are shown in Figure IV-1 and listed in Table IV-1.

A review of possible relationships indicates that for the river ranges #2 and #5 there doesn't appear to be any dependence upon rainfall conditions. As shown in Figure IV-9 the data for EC results might be associated with some relationship to the river flow, but correction for river flow changing the EC content from a concentration to a quantity actually results in little change in the pattern.

On the other hand the information in Figure IV-8 does indicate a possible strong influence by rainfall on the pollution levels in the tidal portion of the river as indicated for ranges #7 and #8 for the 14th. Figure IV-10 really appears to clinch this relationship of high counts in the estuary to rainfall. Also indicated on Figure IV-10 would appear to be an inverse relationship between tidal range and bacterial levels. Because of the influence of rain on the 14th and 15th it is necessary to compare non-rain periods with the tidal range pattern to see this probable relationship. This conforms with the expected since less flushing of the upper tidal area would be anticipated with lower tidal exchanges and hence less dilution by the sea water and thus higher counts. Since salinity data and other data, such as longer period of record, is not available to support this, it might be best left as a strong probability.

The direct relationship to rainfall and, to a more limited extent, the inverse relationship to tidal range, continue for the EC data and for the data for the other ranges proceeding seaward. As noted in Figure IV-13 apparently this rainfall-caused peak comes a day later at range #14. A similar pattern occurs at the other seaward stations as shown in Figure IV-14. In addition the effect appears to remain for a few days apparently then coming under the influence of the tidal range effect.

Since the area of most concern for the future of shellfish production would be the Oak Bay area, it is necessary to concentrate on the relationship of this area to the pollution sources. Figures IV-15, IV-16 and IV-17 give this picture. The fact that range P is seaward of range C and has higher pollution levels supports the pollution source information that the major sources are the Calais, St. Stephen area. Again the effect in this area is delayed a day from that causing the increase at the pollution sources. It might be expected that the time of travel for pollution from the sources to this area would be the shortest when the tidal range is largest, since

this would mean less time for the pollution to stay in the arm of the estuary leading up to Calais. This seems to be verified by the apparent relationship between tidal range and bacterial level as indicated in Figure IV-17. The rainfall appears to have overcome somewhat the normal downward trend that would have been expected for the 14th. It should be noted that for range #14 and for the ranges in Oak Bay the effect of rainfall is felt on the day of rain but the peak doesn't occur until the next day. The patterns for EC support this trend.

Another way of looking at these relationships is to study the log probability plots of the data for the various ranges. The similarity of slopes for the various ranges appears significant as does the variation over a given range. The plot for range #7 is very uniform with the points all close to the "eye-fit" straight line indicating a single population of study. Other factors appear to influence the source pollution such that the results appear to be that resulting from several population control factors, such as tide, etc. Shown on Figure IV-19 and IV-20 is a plot of the same data broken down according to rainfall and tidal phase effect. It should be recognized that the rainfall and tidal phase data may interact and influence each other.

The information seems to indicate that rainfall acounts for the higher values as expected. Of even more importance is the indication that during periods of rainfall the bacterial counts reach a peak level which they appear not to exceed. This is evidenced by the very flat slope of the higher values for the rainfall plot for all ranges. Although it would require further studies to verify this condition it is very significant to the present consideration. In the case of combined sewer systems that overflow during periods of rain it is very significant in determining the applied pollution load to be able to know whether the magnitude of pollution load is related to the intensity of the rainfall, the total amount of rainfall, both, or beyond a certain level, neither. The flatness of the slope of the rainfall data appears to indicate that beyond a certain point the rainfall ceases to increase the pollution contribution. This is what might be expected for a situation where once the sediment has been flushed from the combined sewer the increase in the pollution load is then related only to the reduced time that the sewage stays in the sewer system before being discharged.

The log probability plots for the tidal range effect, Figure IV-20, seem to confirm the previous supposition, namely that the higher counts would occur in the area below Calais at times of lower tidal range and that the reverse would be the trend at range C in the shellfish area. Again it is necessary to recognize that the rainfall effect influences these results somewhat.

Summary and Recommendations

In the estuary system of the St. Croix the MF, MPN or EC test may be utilized as the indicator. In area classification the MF or MPN appear to be equivalent with the guiding value of 70 per 100ml governing. If the EC were to be utilized a value one-tenth of this would be used in area classification as being equivalent. In this review the MF results are utilized since they were collected for all stations on a range and hence are more numerous for each cross-section under study.

The primary condition affecting results appears, beyond a doubt, to be rainfall as it affects the quantity and strength of the pollution contribution from the combined sewer systems in the communities. To a lesser degree is the tidal range. This affect appears to result in a peak condition which is not exceeded by more intense or longer duration storms.

Before stating with a certainty the above conclusions it would be necessary to study the quantity and concentration relationships of the sewage coming from the sewer outlets in the major contributing communities. These relationships would have to be compared with rainfall intensity and duration information.

In addition it would be necessary to study, at least, ranges #7, #14 and C during this period of time including data on tidal range, and salinity variations, as well as continued bacteriological studies. Both this and the sewer system studies would have to cover rainfall conditions in the fall as well as the spring thaw period when temperatures are generally considered more favorable for bacterial survival. The spring thaw would be considered as affecting the storm water contributions to the combined sewer system as well.

During the 1963 period of study the "most unfavorable condition" is considered as that related to the heavy rains on the 14th and 15th and accordingly the results of this and those related to this rainfall are given in Figure IV-21. They are practically the same as the maximum figures as given in the summary figure, Figure IV-22.

TABLE IV-1. ST. CROIX RIVER SAMPLING STATIONS -- 1963

- RIVER TO HEAD OF TIDE -

Range	Location	Distance from Pulp Mill
V*	International Bridge between Vanceboro, Me. and St. Croix, N.B.	35.0 mi. upstream
2*	Pulp mill at Woodland, Me.	200 yds. downstream
2(c)	Pulp mill at Woodland, Me.	300 yds. downstream (below equalizing tank)
5*	International Bridge between Milltown, Me., and Milltown, N.B.	8.7 mi. downstream
7*	International Bridge between Calais, Me. and St. Stephen, N.B.	10.5 mi. downstream

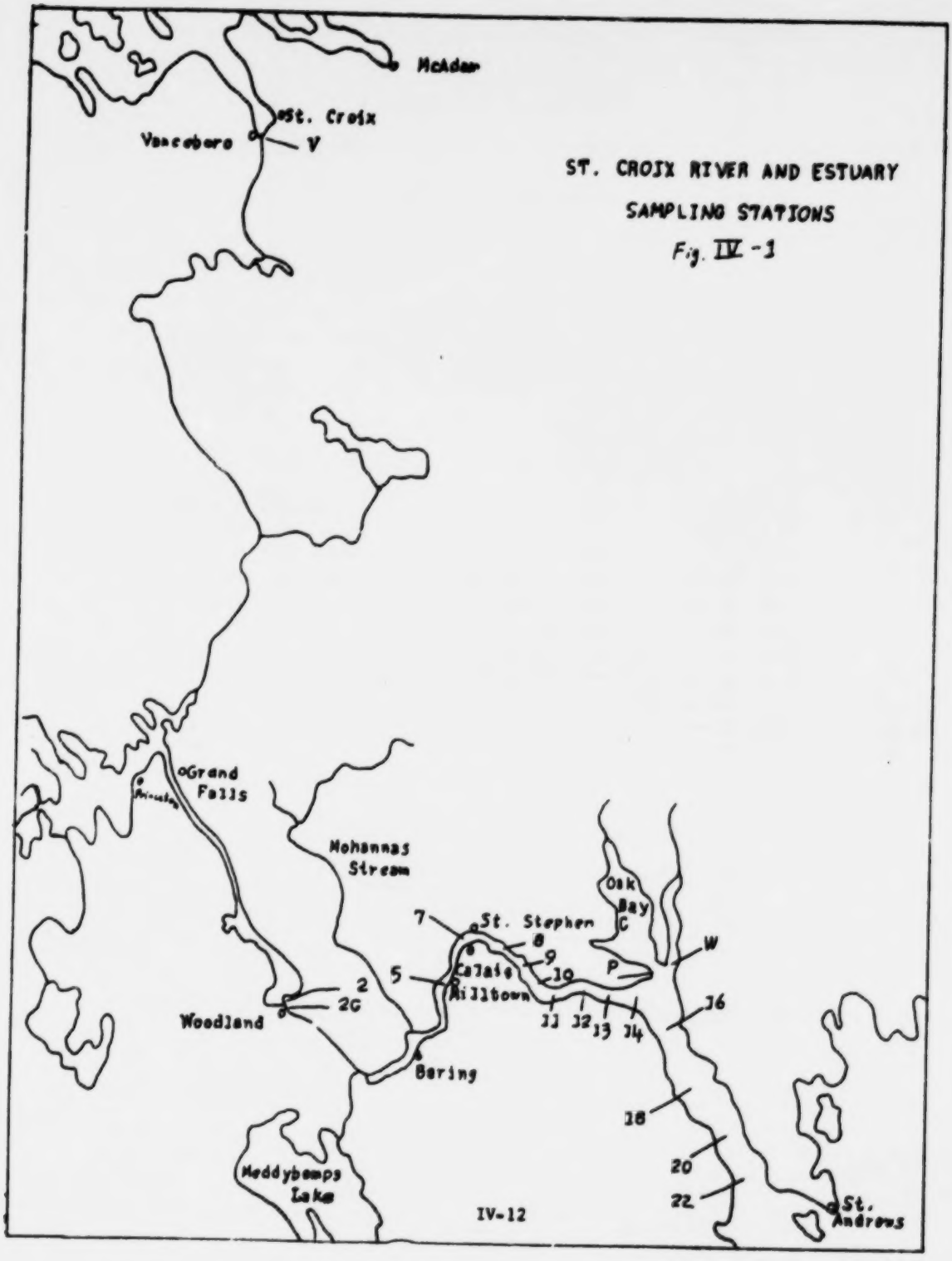
- RIVER AND ESTUARY FROM HEAD OF TIDE -

8	Mid. River 1.0 mi. below Stn. 7	11.5 mi. downstream
9	Mid. River 2.0 mi. below Stn. 7	12.5 mi. downstream
10	Mid. River 3.5 mi. below Stn. 7	14.0 mi. downstream
11	Mid. River 4.5 mi. below Stn. 7	15.0 mi. downstream
12	Mid. River 6.0 mi. below Stn. 7	16.5 mi. downstream
13	Mid. River 7.0 mi. below Stn. 7	17.5 mi. downstream
14	Mid. River 8.0 mi. below Stn. 7	18.5 mi. downstream
16	Mid. River 9.0 mi. below Stn. 7	19.5 mi. downstream
18	Mid. River 10.0 mi. below Stn. 7	20.5 mi. downstream
20	Mid. River 12.0 mi. below Stn. 7	22.5 mi. downstream
22	Mid. River 13.5 mi. below Stn. 7	24.0 mi. downstream

- OAK BAY -

C	Section (W to E)	at Campbell Pt.
W	Section (W to E)	at Waweig River
P	Section (W to E)	at Plaisler Pt.

*Fixed sampling stations established for prior river surveys.



ST. CROIX RIVER AND ESTUARY

SAMPLING STATIONS

Fig. IV -1

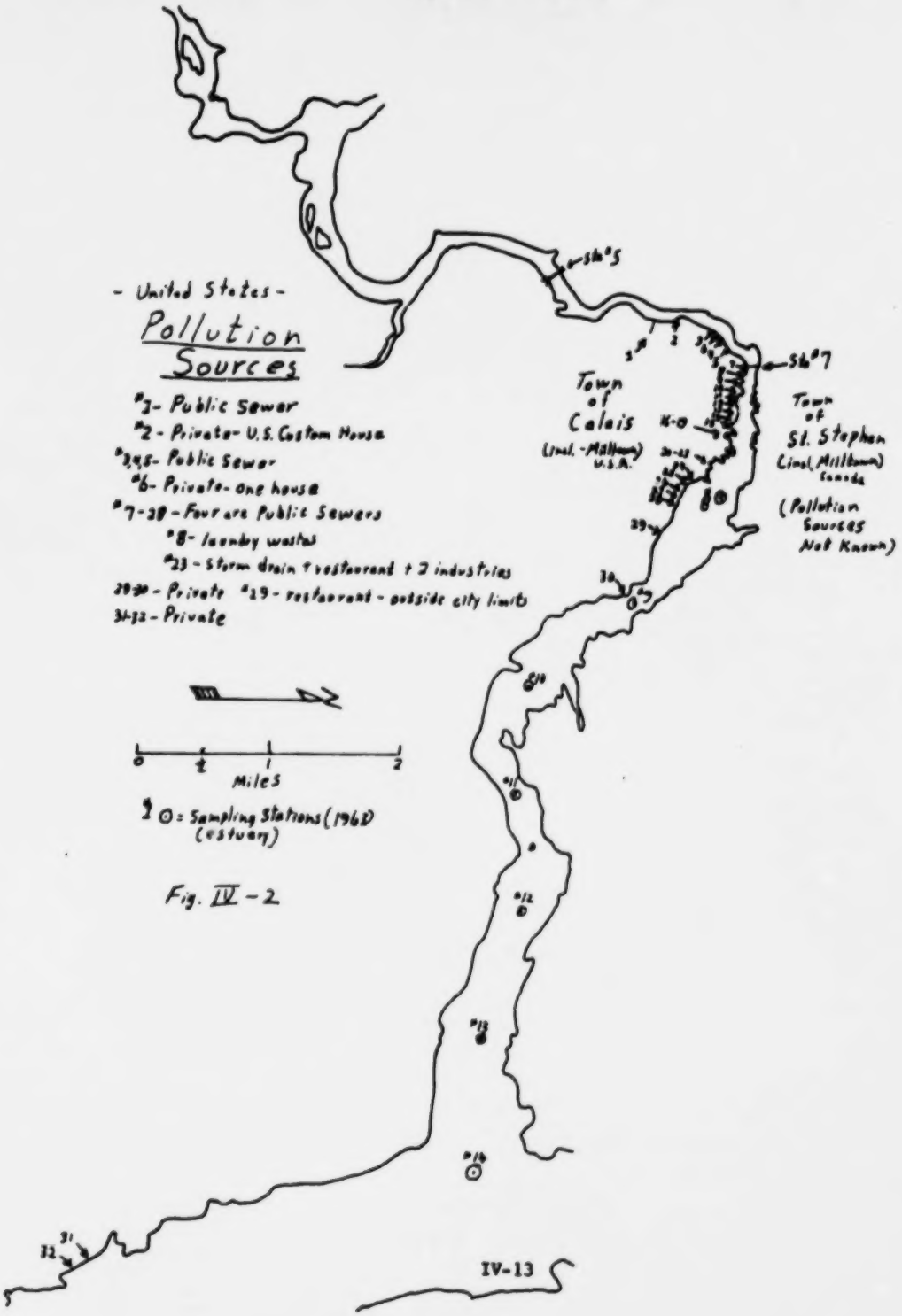

- United States -
Pollution Sources
#3- Public Sewer
#2- Private- U.S. Custom House
#3,4,5- Public Sewer
#6- Private- one house
#7-28- Four are Public Sewers
#8- laundry wastes
#23- Storm drain + restaurant + 2 industries
29-30- Private #29- restaurant - outside city limits
31-32- Private
Sta #5
Sta #7
Town of Calais (Incl. - Milltown) U.S.A.
Town of St. Stephen (Incl. Milltown) Canada
(Pollution Sources Not Known)
0 1/2 1 2
Miles
= Sampling Stations (1969 (estuary)

Fig. IV-2

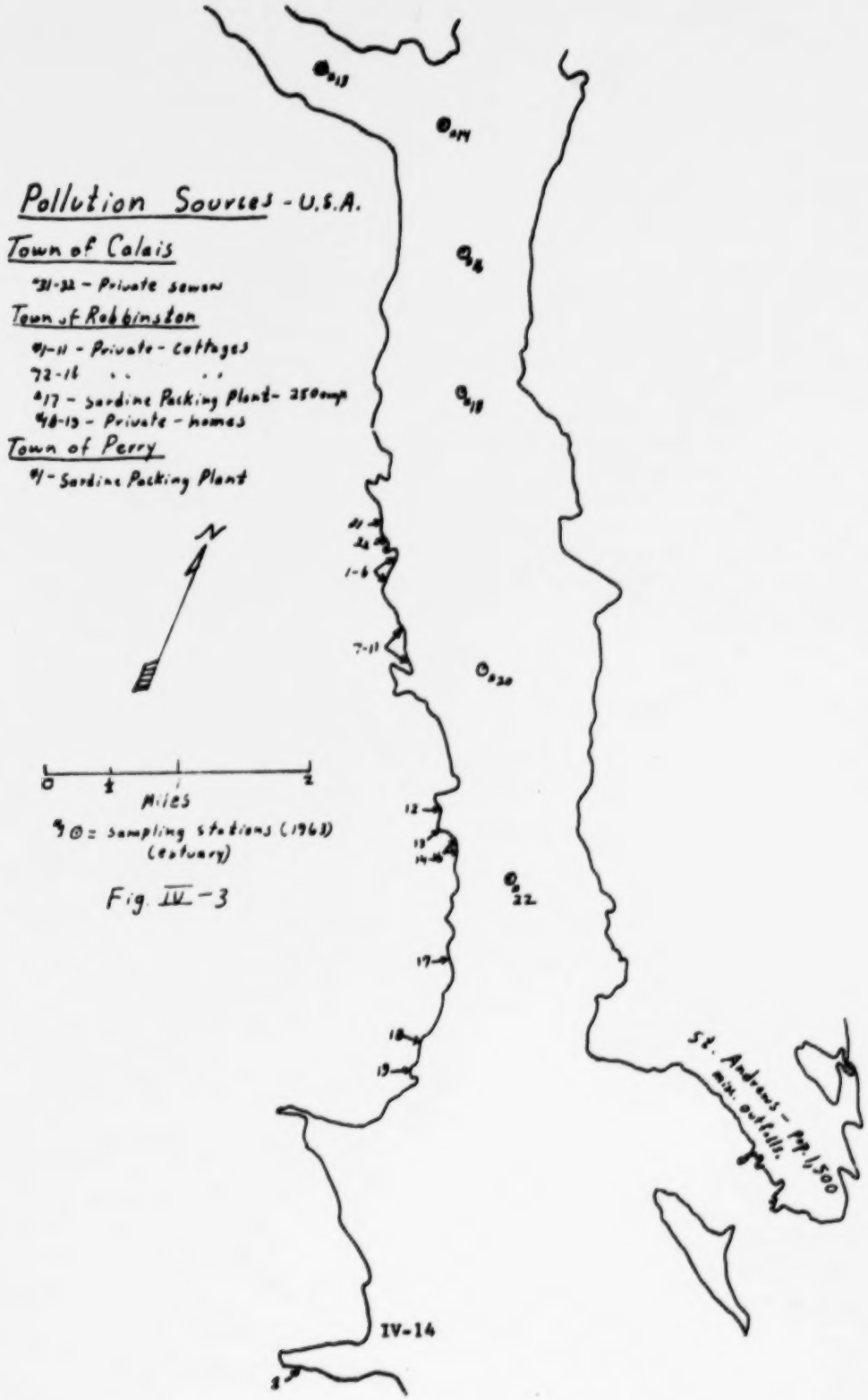

Pollution Sources - U.S.A.
Town of Calais
*21-22 - Private sewers
Town of Robbinston
1-11 - Private - cottages
12-16 " "
*17 - Sardine Packing Plant - 250 emp.
18-19 - Private - homes
Town of Perry
1 - Sardine Packing Plant
N
0
1
2
Miles
1@ = sampling stations (1961)
(estuary)
1-6
7-11
12
17
18
19
St. Andrews - pop. 1,500
min. outfalls.

Fig. IV-3

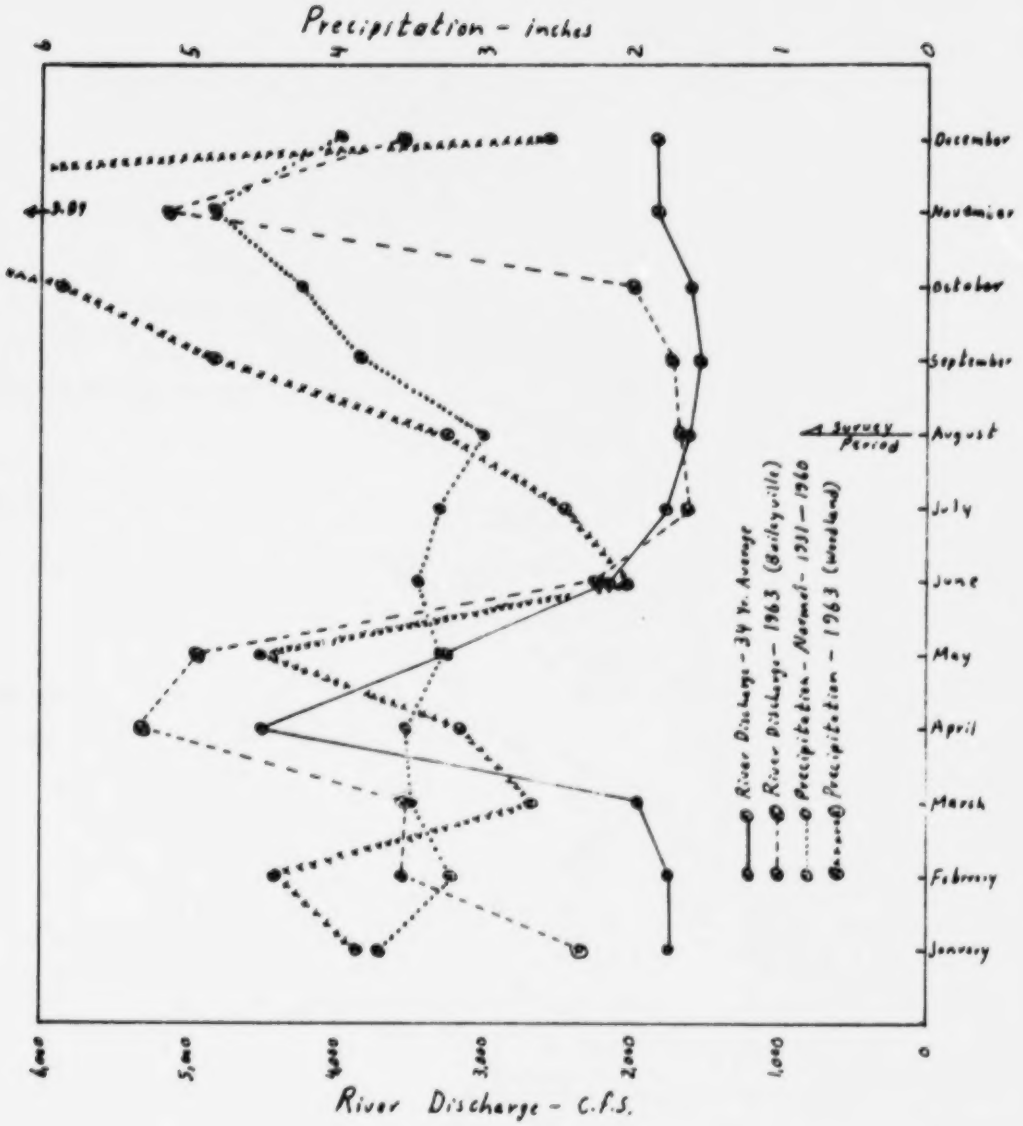

Precipitation - inches
6
5
4
3
2
1
0
3.89
December
November
October
September
August
July
June
May
April
March
February
January
Survey Period
River Discharge - 34 Yr. Average
River Discharge - 1963 (Baileyville)
Precipitation - Normal - 1931 - 1960
Precipitation - 1963 (woodland)
6,000
5,000
4,000
3,000
2,000
1,000
0
River Discharge - C.F.S.

Fig IV - 4

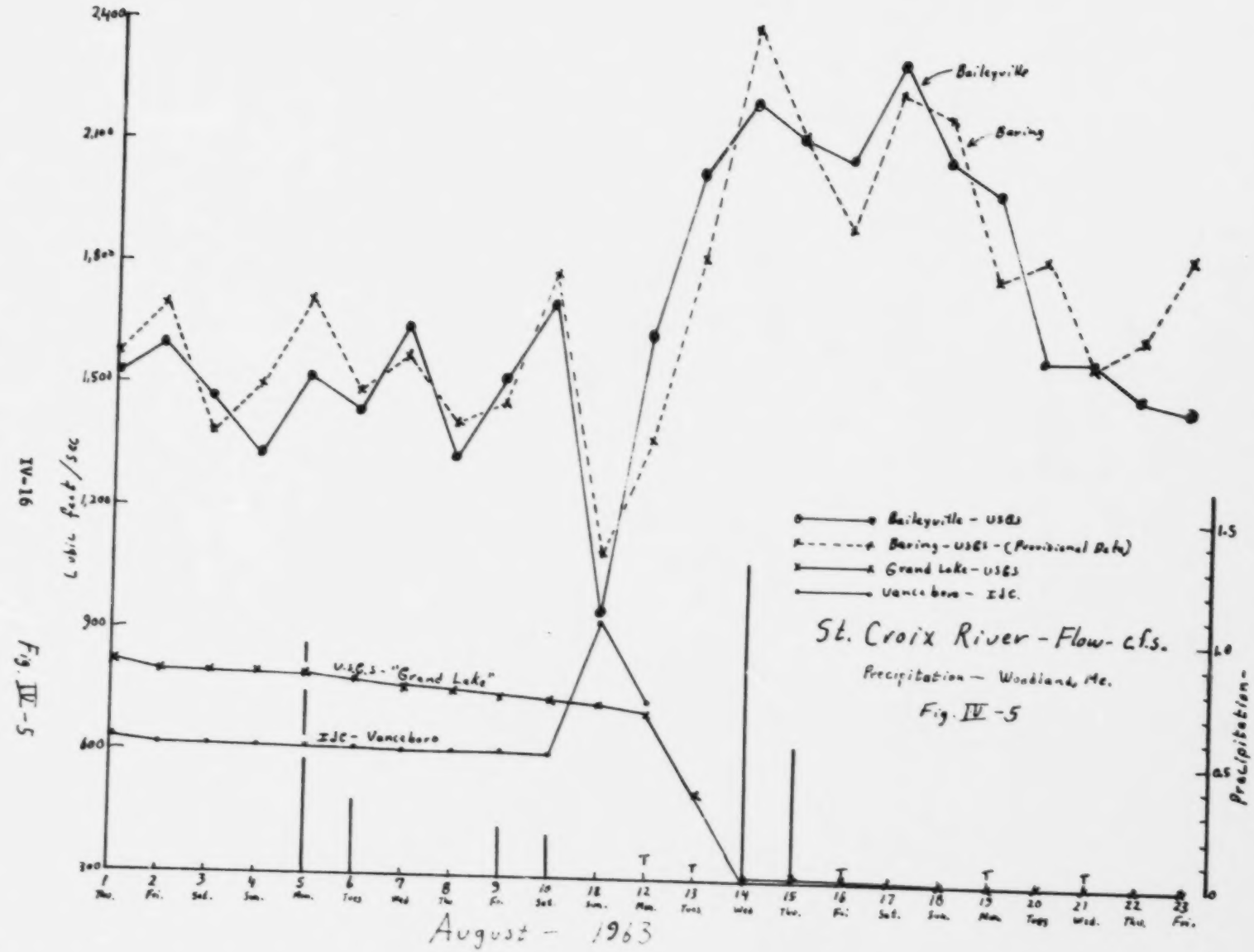

2,400
2,100
1,800
1,500
1,200
900
600
300
Cubic Feet/Sec
Baileyville
Baring
Baileyville - USGS
Baring - USGS - (Provisional Data)
Grand Lake - USGS
Vanceboro - IJC.
St. Croix River - Flow - c.f.s.
Precipitation — Woodland, Me.
Fig. IV-5
U.S.G.S. - "Grand Lake"
IJC - Vanceboro
1.5
1.0
.5
0
Precipitation -
1 Thu.
2 Fri.
3 Sat.
4 Sun.
5 Mon.
6 Tues
7 Wed
8 Thu
9 Fri.
10 Sat
11 Sun.
12 Mon.
13 Tues
14 Wed
15 Thu.
16 Fri
17 Sat.
18 Sun.
19 Mon
20 Tues
21 Wed.
22 Thu.
23 Fri.
T
August - 1963

Fig. IV-5

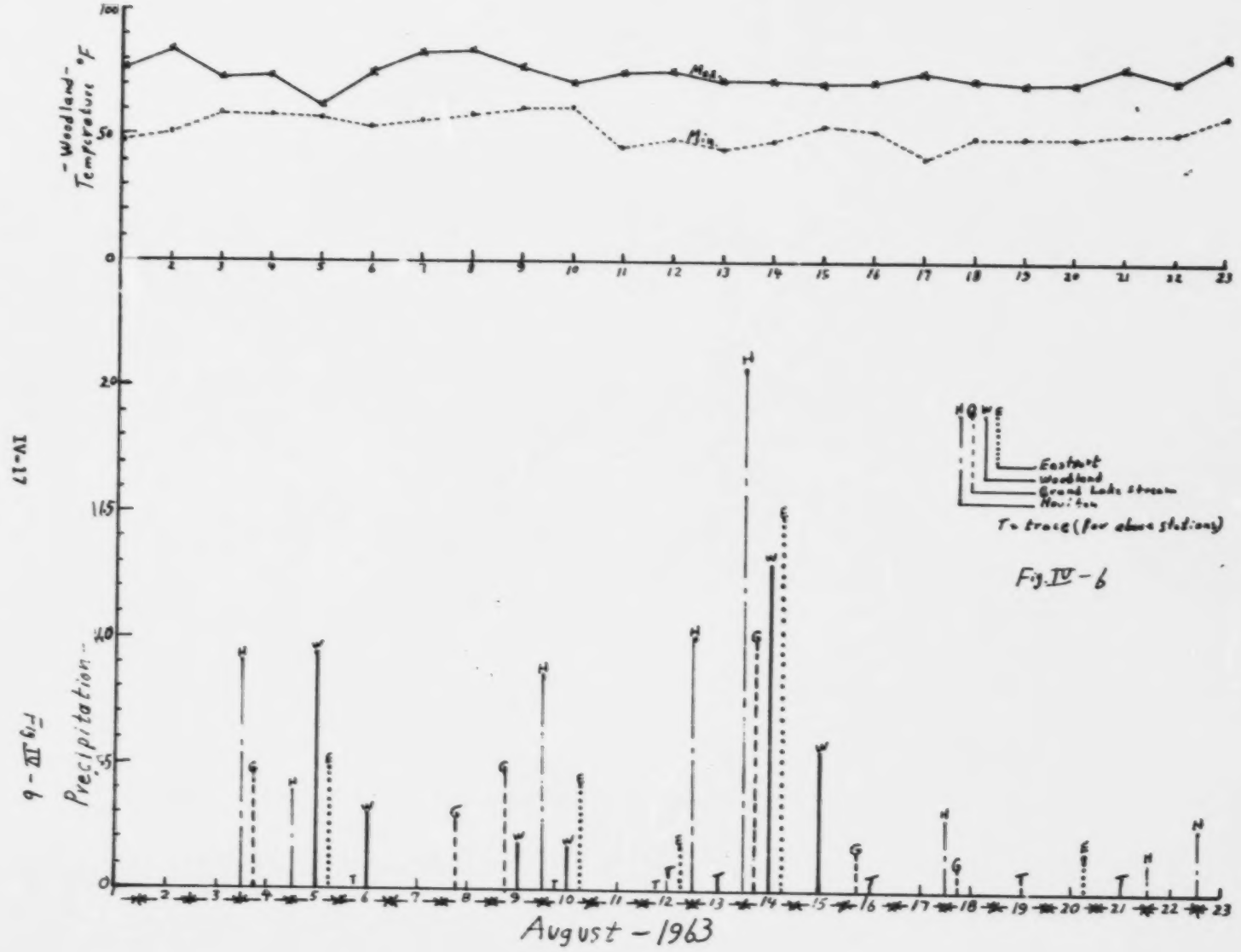


Fig. IV-6

IV-17

9 - IV 6/1

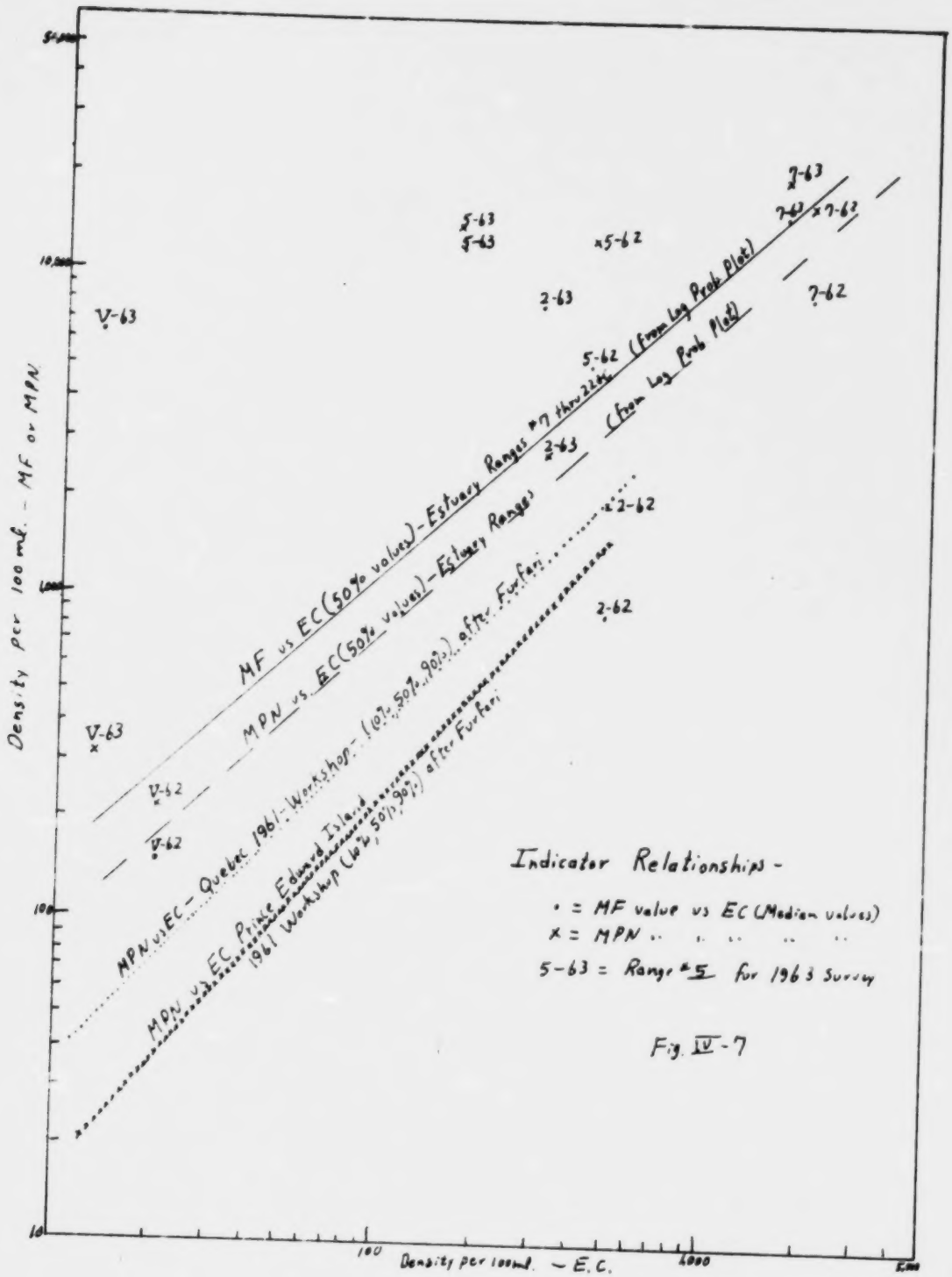

Density per 100 ml. - MF or MPN
Density per 100 ml. - E.C.
MF vs EC (50% values) - Estuary Ranges P7 thru 22 Mi.
MPN vs EC (50% values) - Estuary Ranges
MPN vs EC - Quebec 1961 Workshop - (10%, 50%, 90%) after Furfari
MPN vs EC Prince Edward Island 1961 Workshop (10%, 50%, 90%) after Furfari
5-62 (From Log Prob Plot)
(From Log Prob Plot)
Indicator Relationships -
• = MF value vs EC (Median values)
× = MPN " " " "
5-63 = Range #5 for 1963 Survey

Fig. IV-7

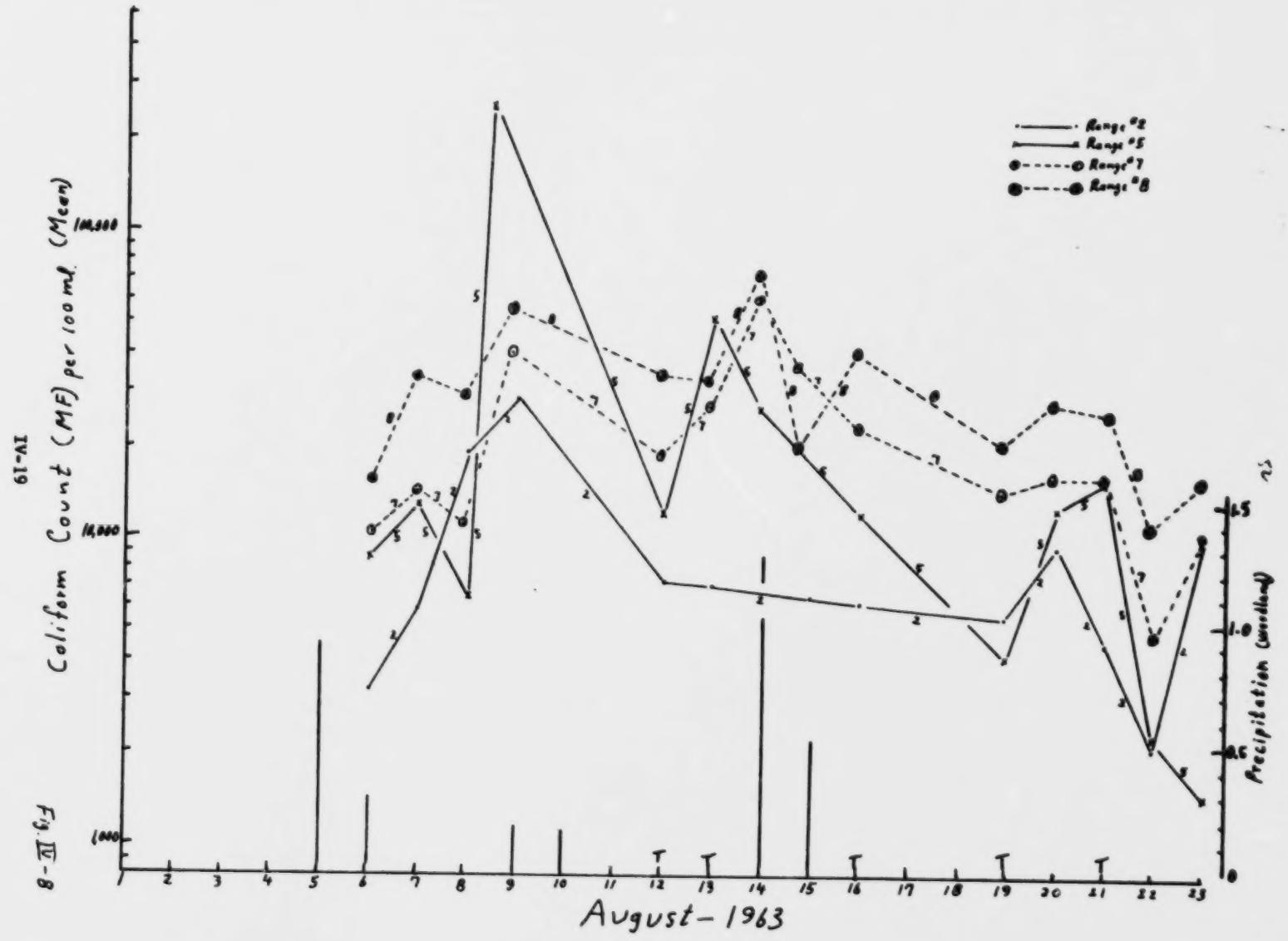
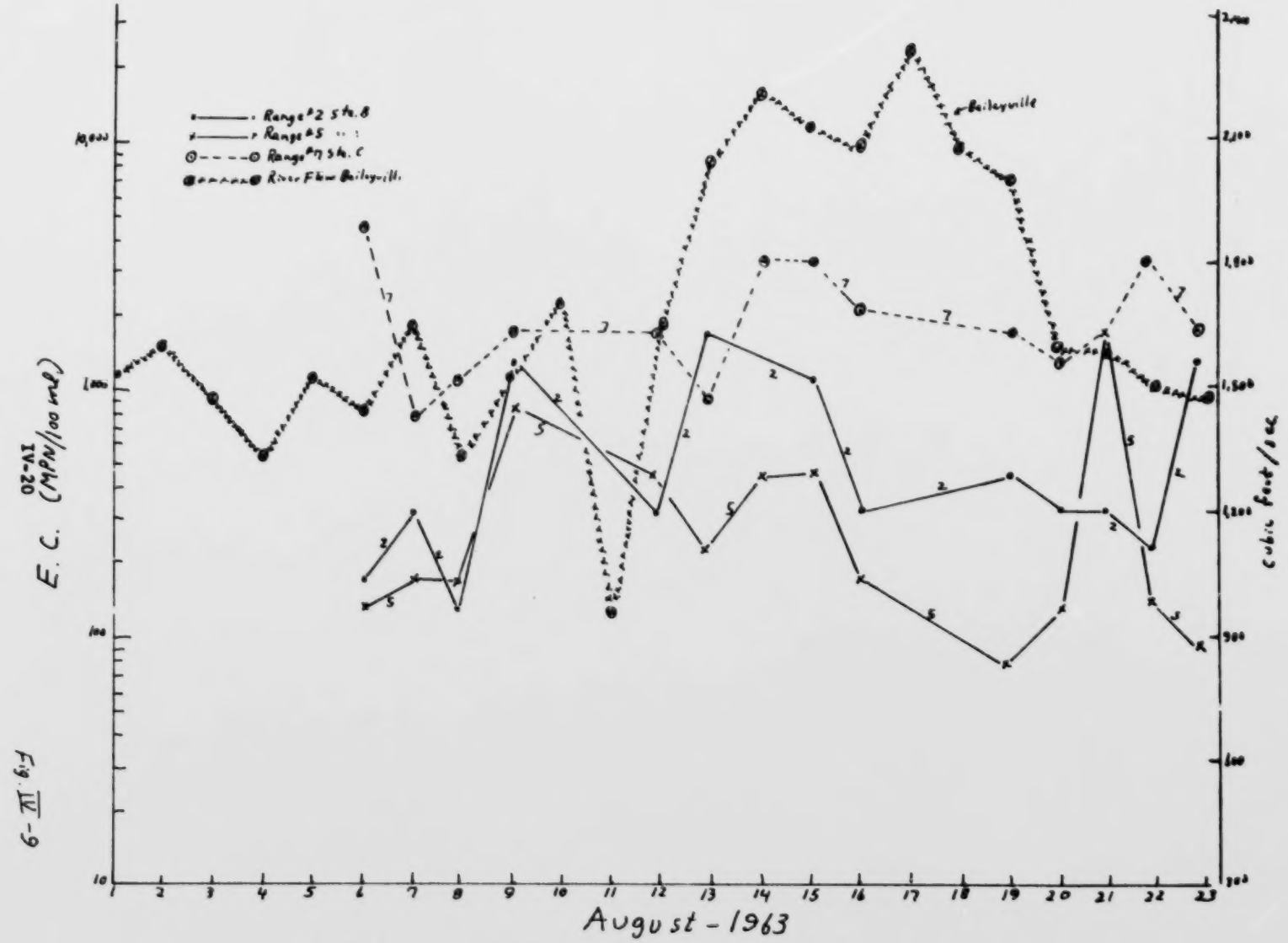

Range #2
Range #5
Range #7
Range #8
Coliform Count (MF) per 100 ml. (Mean)
100,000
10,000
1000
Precipitation (inches)
1.5
1.0
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August - 1963

Fig. II-8

IV-19


Range #2 Sta. B
Range #5 " "
Range #7 Sta. C
River Flow Baileyville
Baileyville
E. C. (MPN/100 ml)
cubic feet/sec
August - 1963

6-XI-63
IV-20

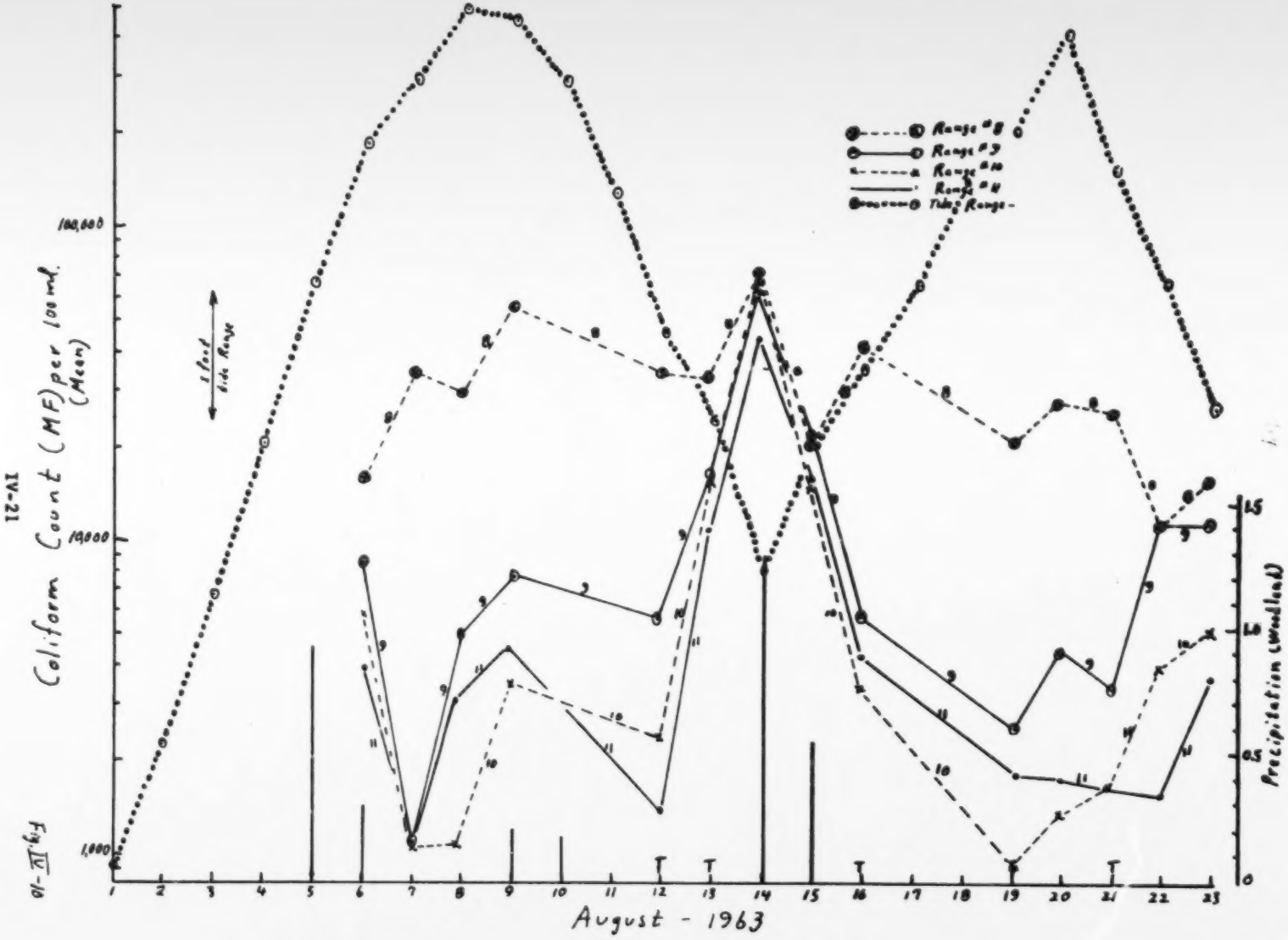
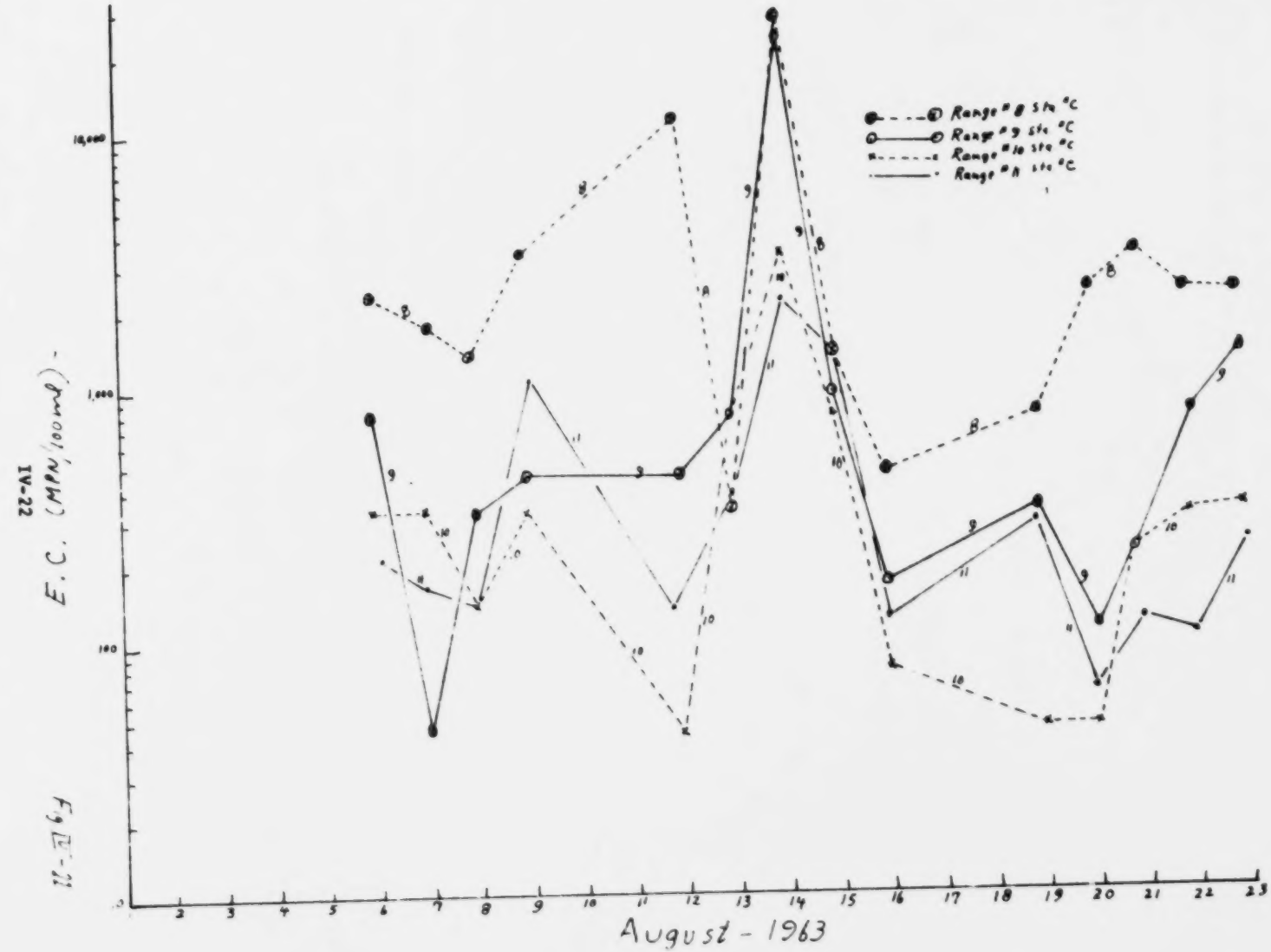

Coliform Count (MF) per 100 ml. (Mean)
100,000
10,000
1,000
Range "B"
Range "3"
Range "10"
Range "4"
Tube Range
1 foot Ash Range
Precipitation (Weather)
1.5
1.0
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August - 1963

Fig. IV-10



IV-22

Fig. IV-21

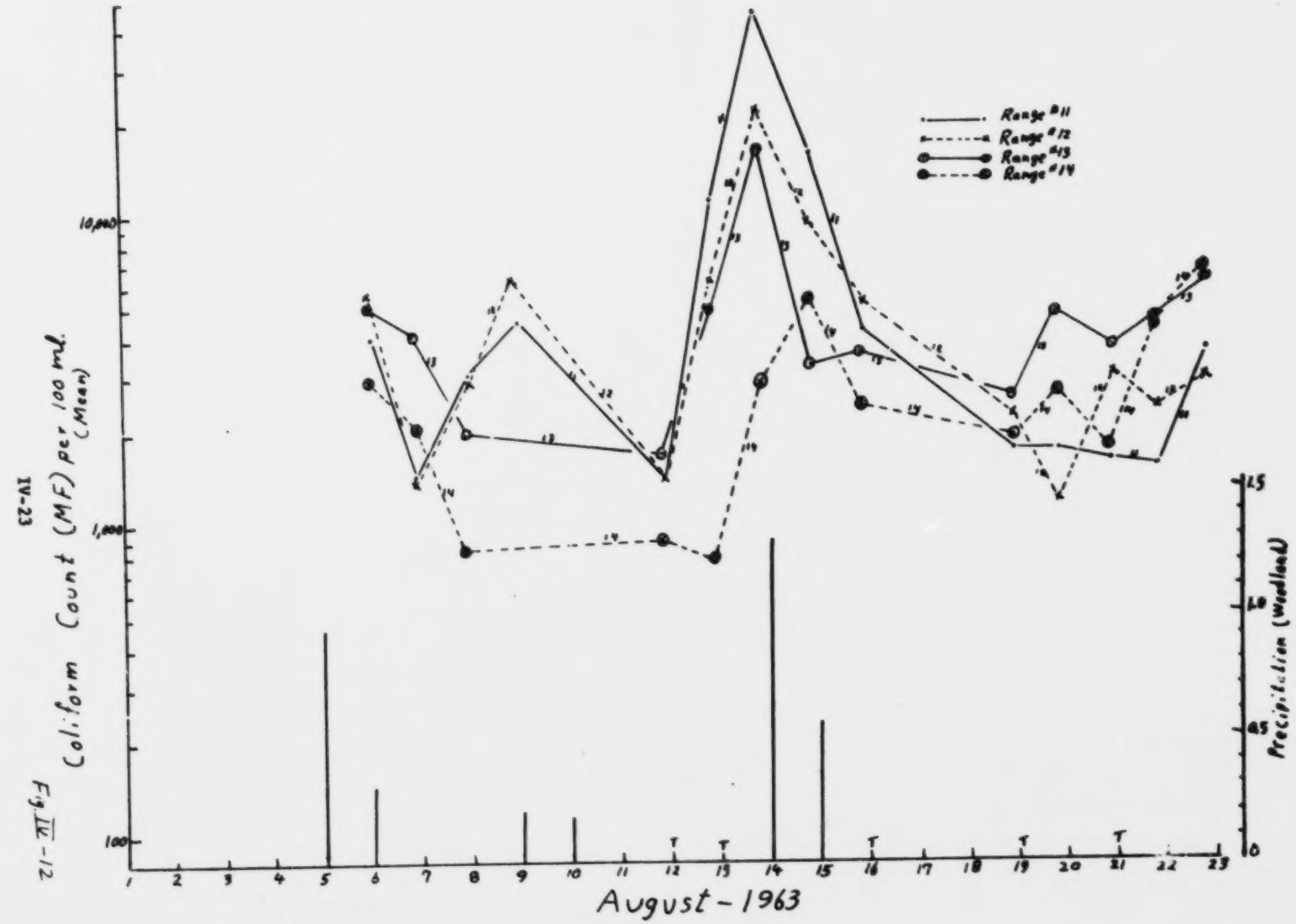
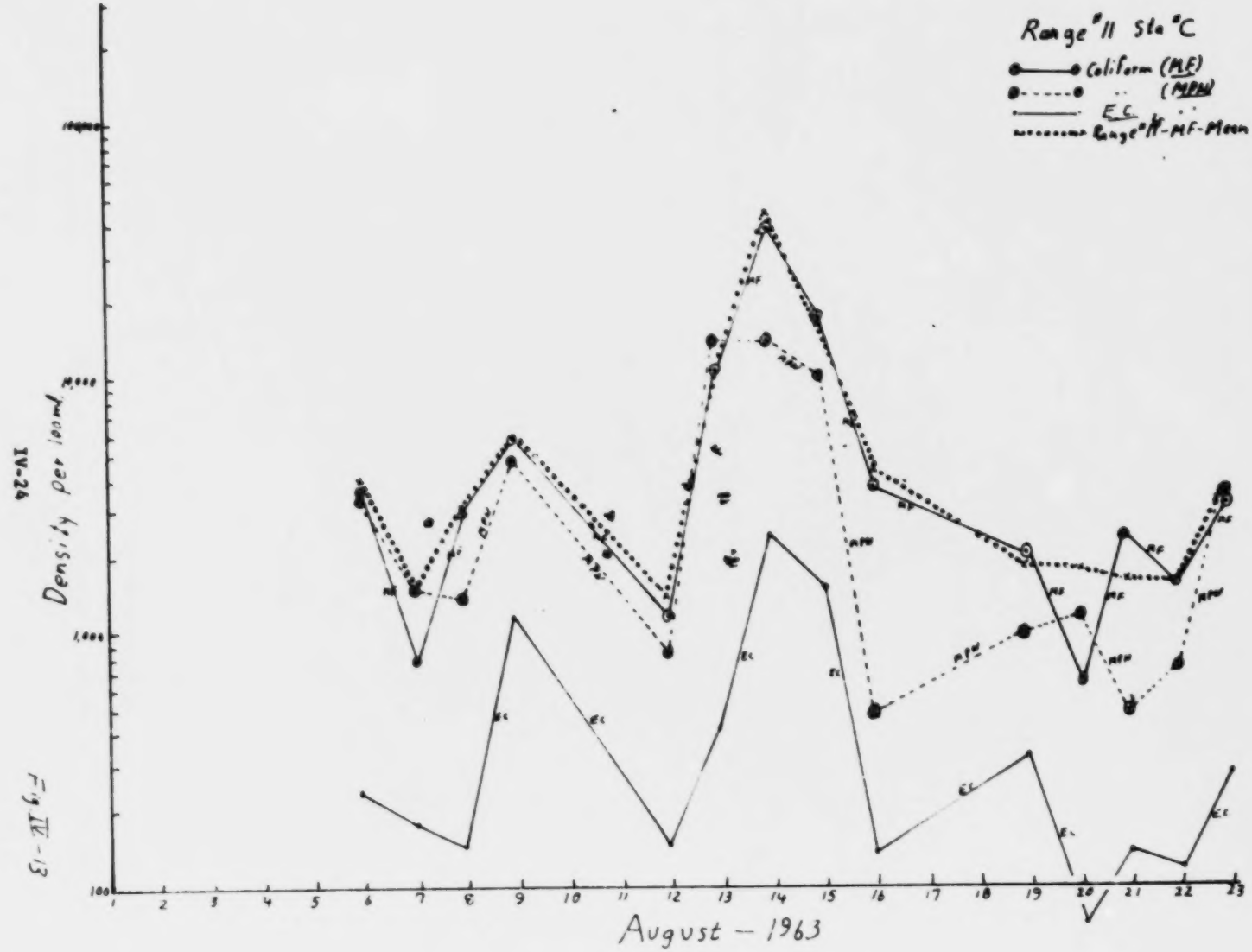
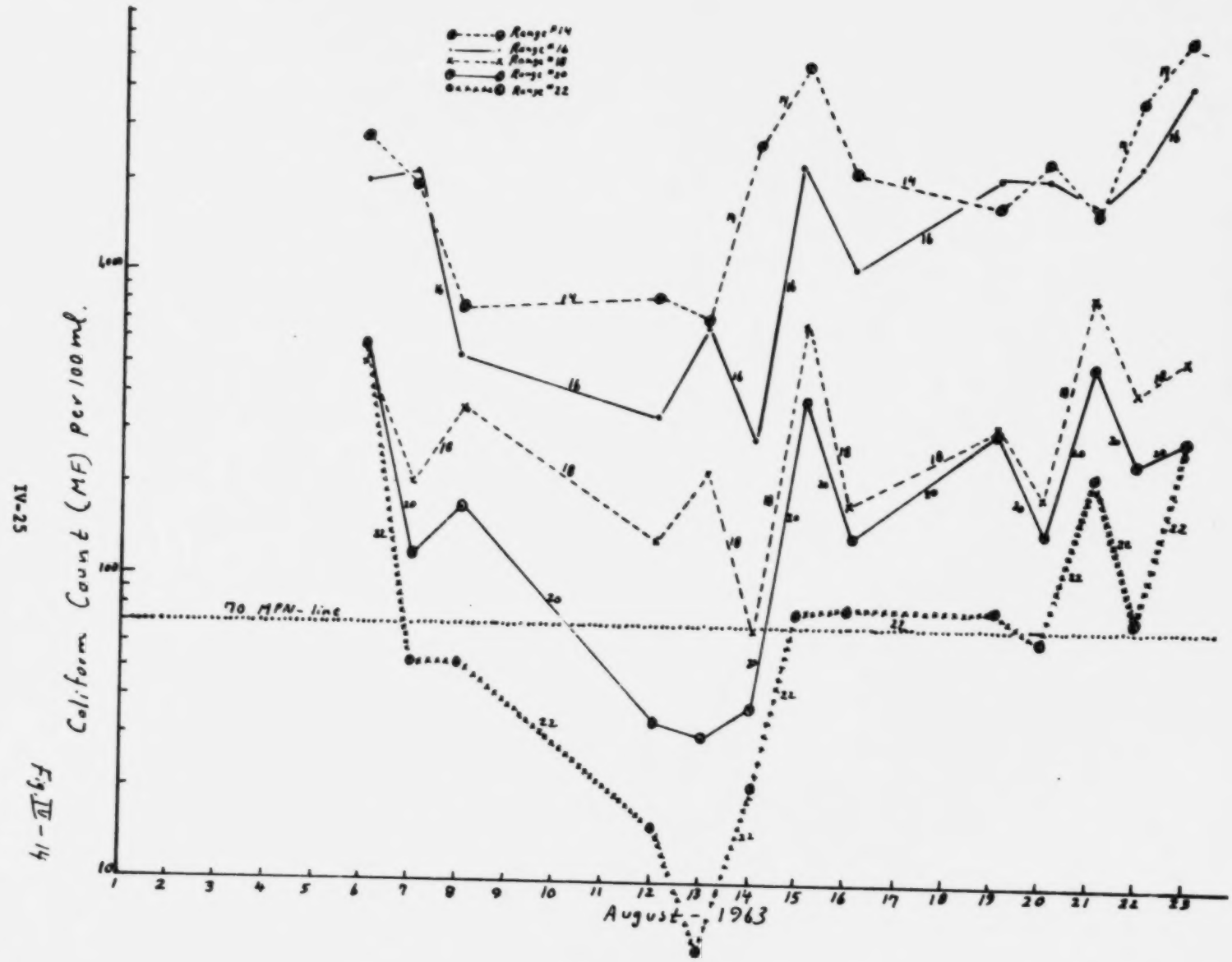

Range #11
Range #12
Range #13
Range #14
10,000
1,000
100
Coliform Count (MF) per 100 ml. (Mean)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August - 1963
T
1.5
1.0
.5
0
Precipitation (Weekend)

Fig. IV-12



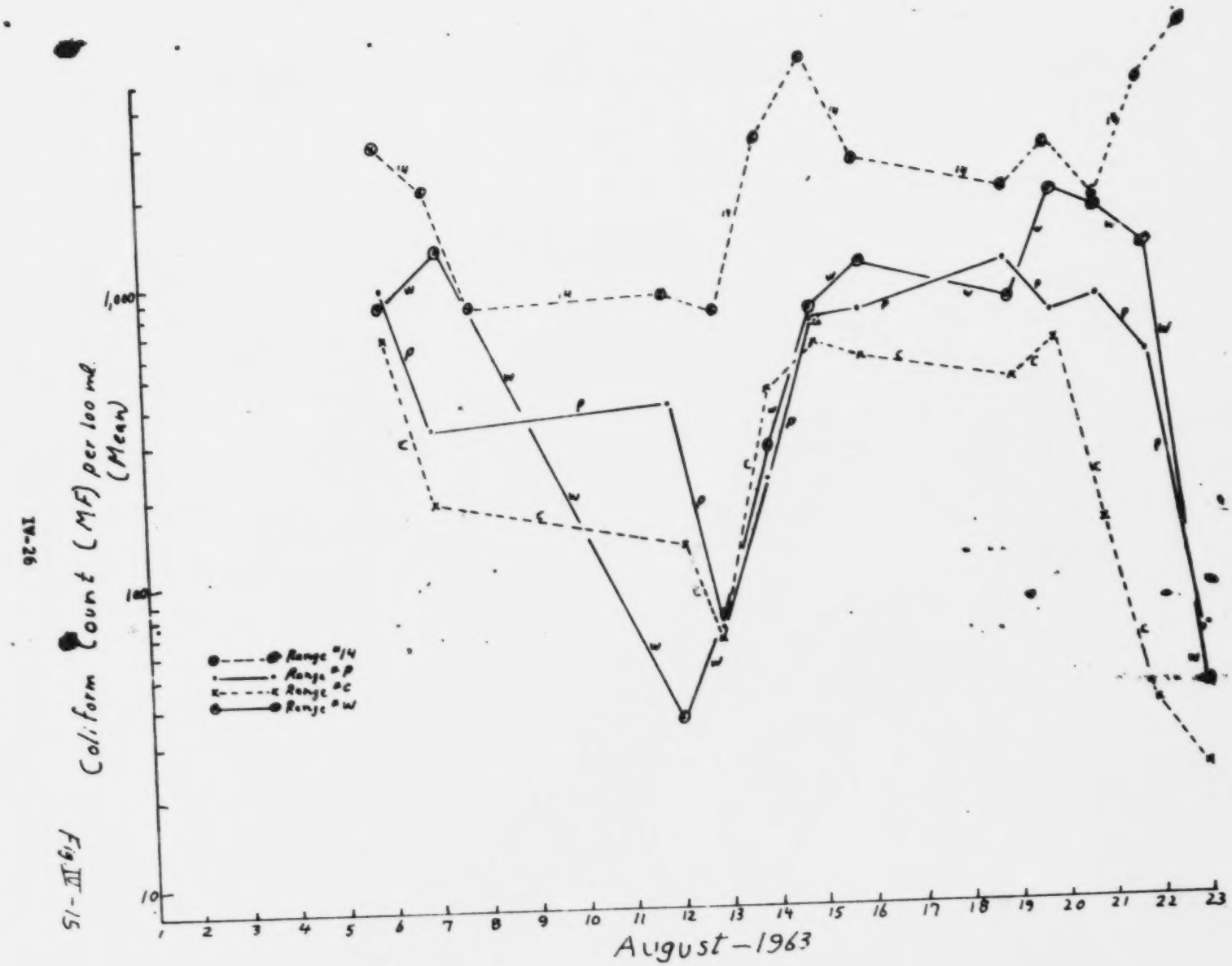
IV-24

Fig IV-13



IV-25

Fig IV-14


Coliform Count (MF) per 100 ml (Mean)
1,000
100
10
Range "M"
Range "P"
Range "C"
Range "W"
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August – 1963

S/- [illegible]

Fig. II

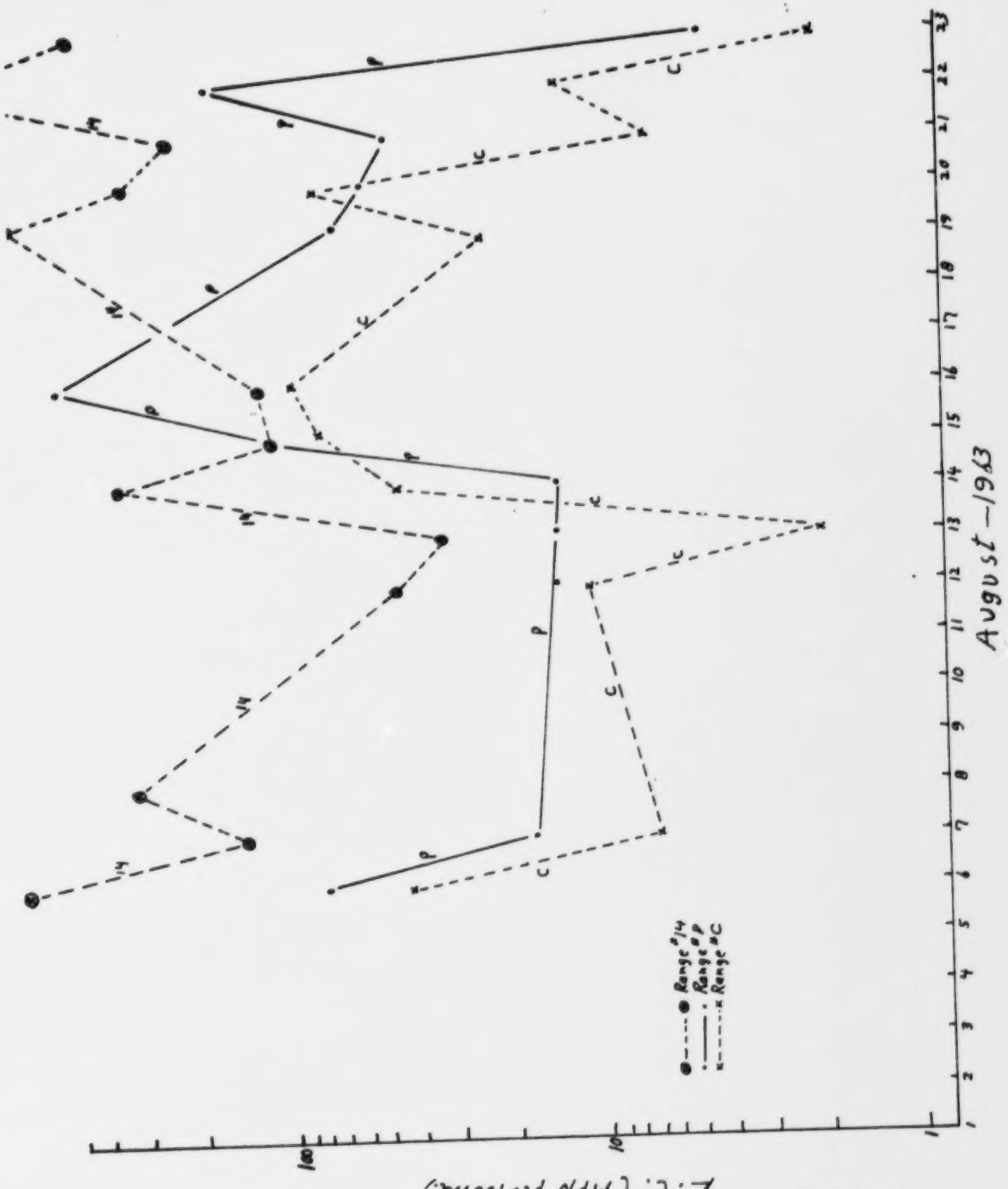
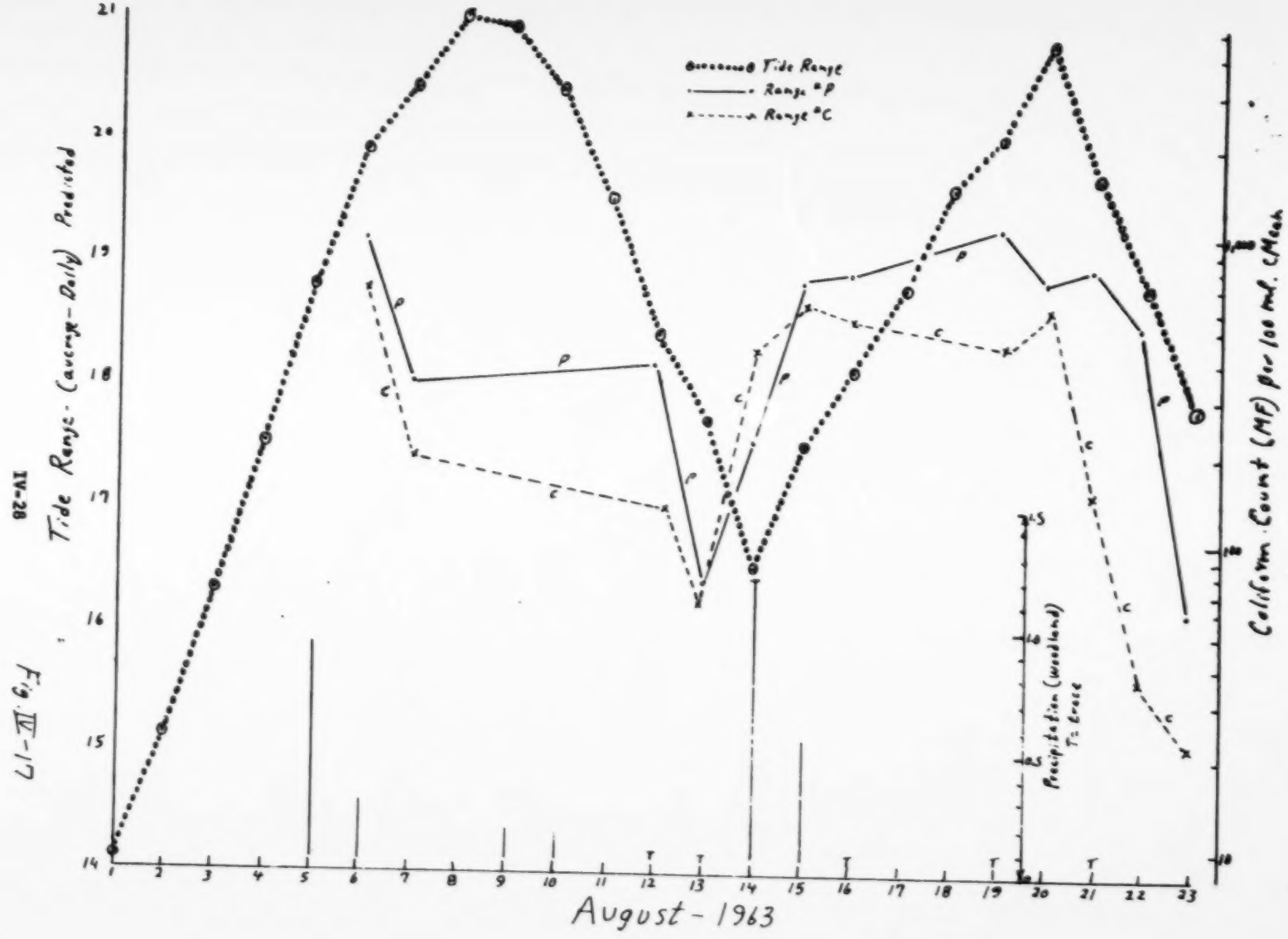


Fig. IV-16



IV-28

Fig. IV-17

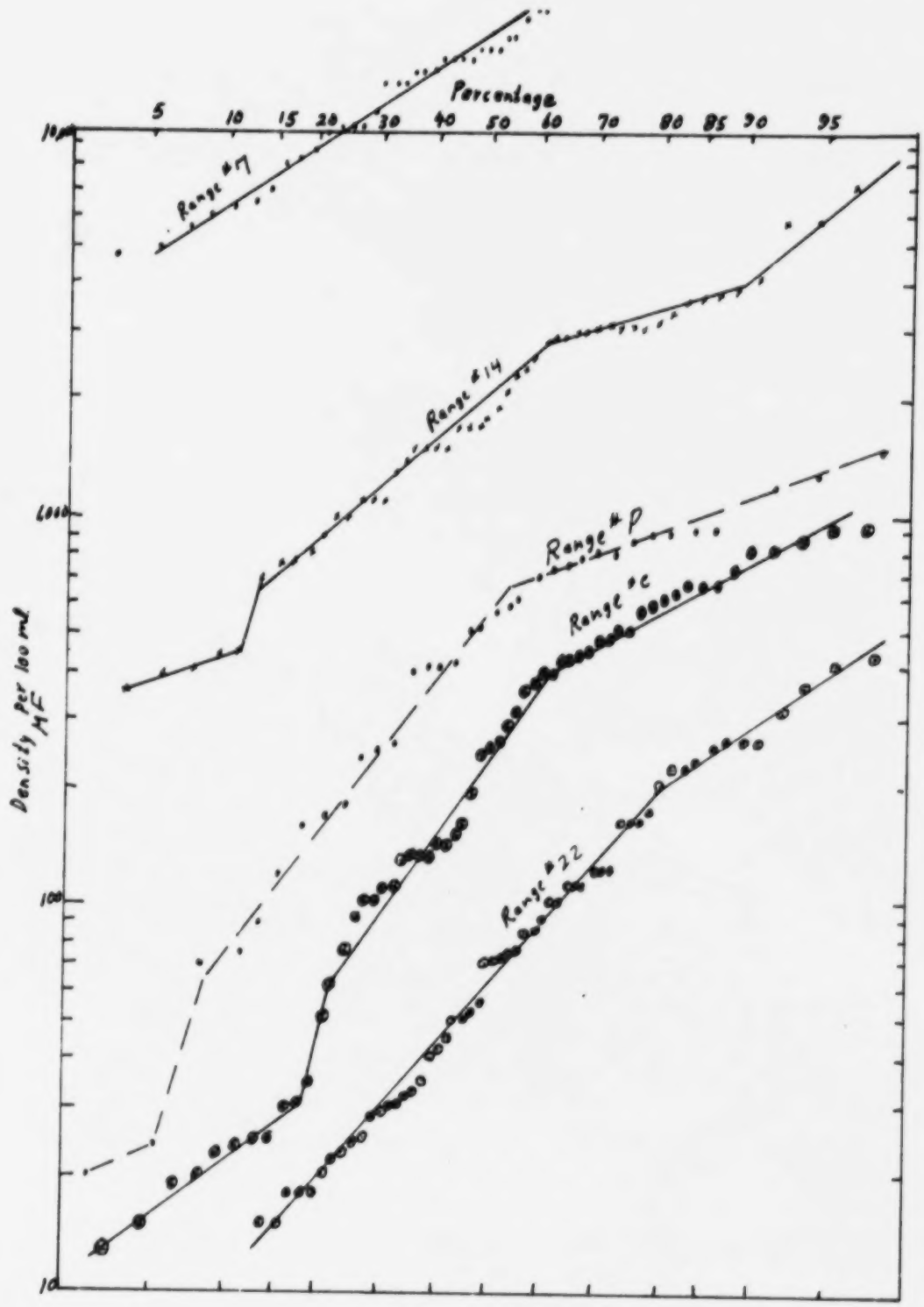

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Range #17
Range #14
Range #P
Range #C
Range #22
Density Per 100 ml
1000
100
10

Fig. IV - 18

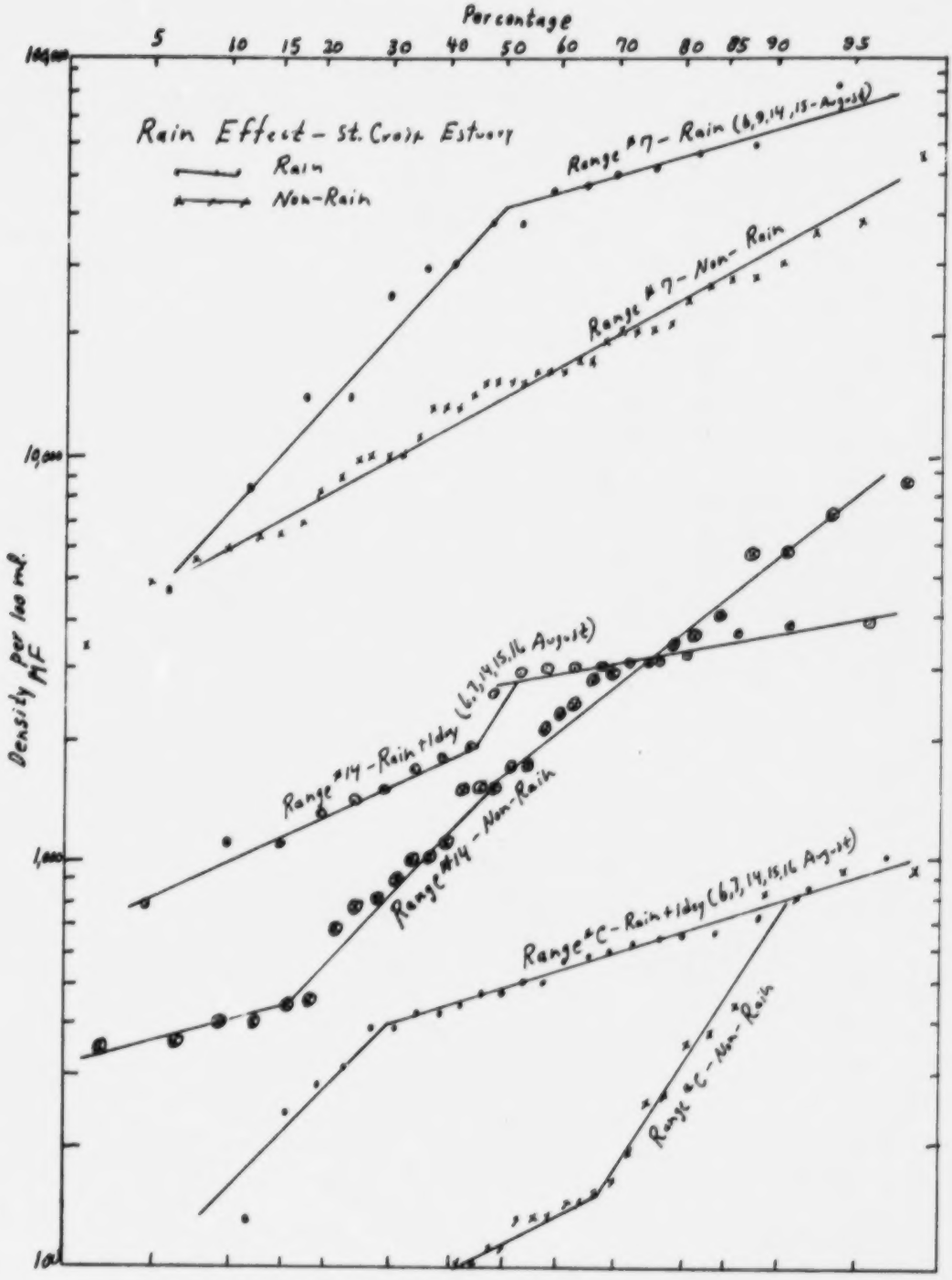

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Rain Effect – St. Croix Estuary
Rain
Non-Rain
Range #7 – Rain (6,9,14,15-August)
Range #7 – Non-Rain
Range #14 – Rain +1day (6,7,14,15,16 August)
Range #14 – Non-Rain
Range #C – Rain +1day (6,7, 14,15,16 August)
Range #C – Non-Rain
Density per 100 ml. MF
10,000
1,000
100

Fig. IV – 19

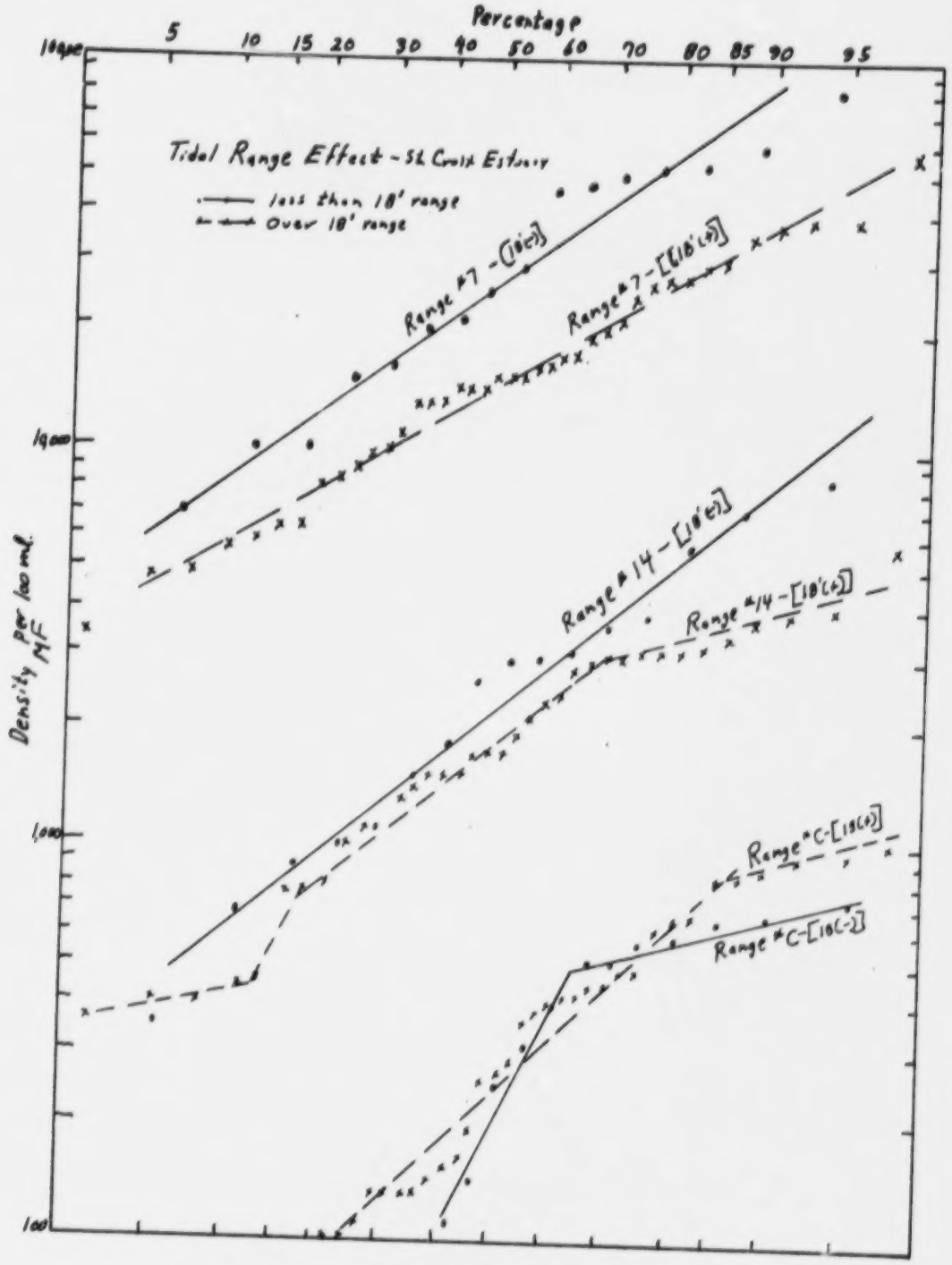

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Tidal Range Effect - St. Croix Estuary
less than 18' range
Over 18' range
Range #7 - [<18'(-)]
Range #7 - [>18'(+)]
Range #14 - [<18'(-)]
Range #14 - [>18'(+)]
Range #C - [<18'(-)]
Range #C - [>18'(+)]
Density per 100 ml
M.F.
100
1,000
10,000

Fig. IV - 20

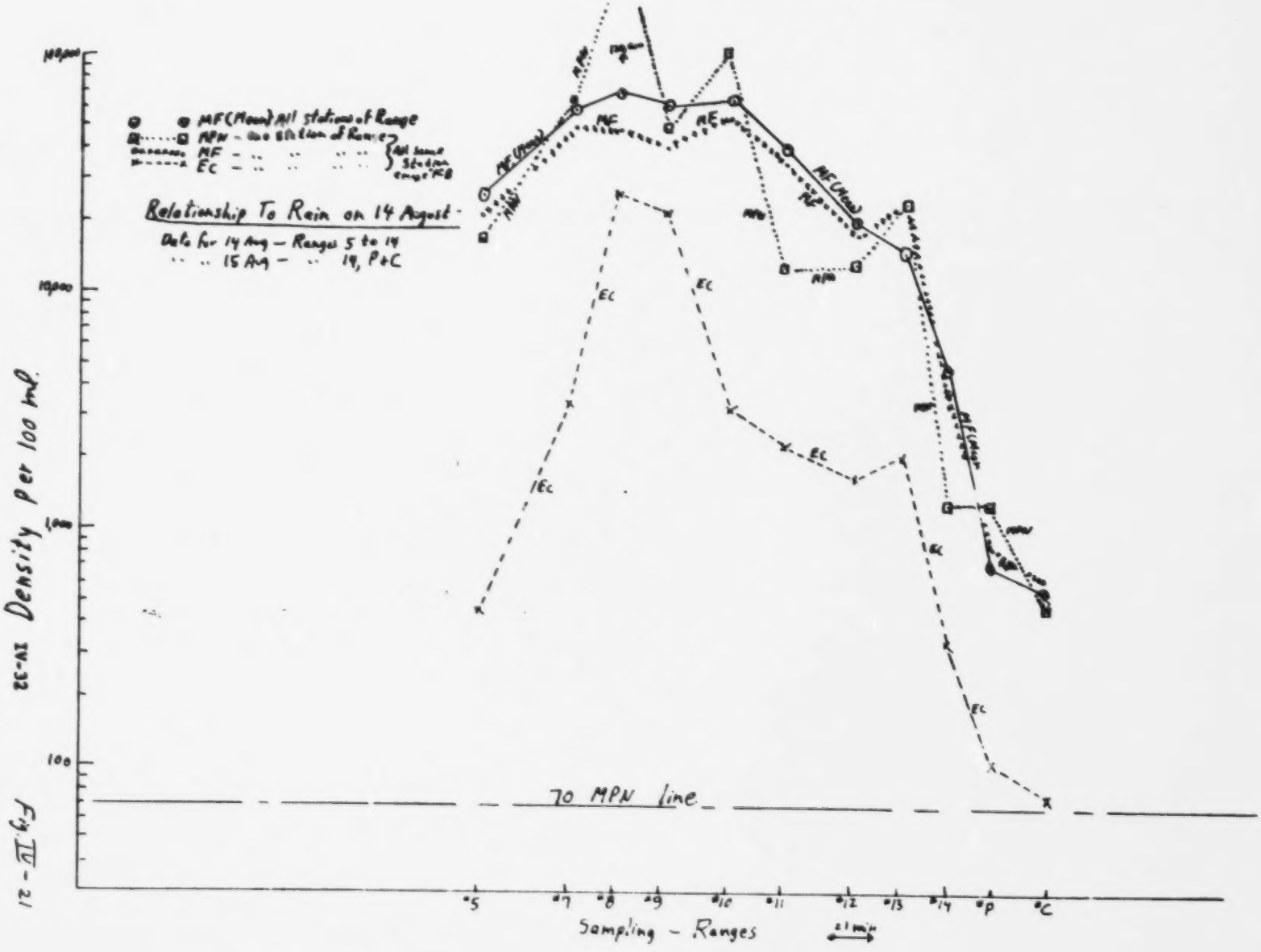

MF (Mean) All stations of Range
MPN - two stations of Range
MF = :: :: :: ::
EC = :: :: :: ::
All same Station range PCB
Relationship To Rain on 14 August -
Data for 14 Aug - Ranges 5 to 14
:: :: 15 Aug - :: 19, P+C
Density Per 100 ml.
70 MPN line
Sampling - Ranges
1 mile

Fig II-12 IV-32

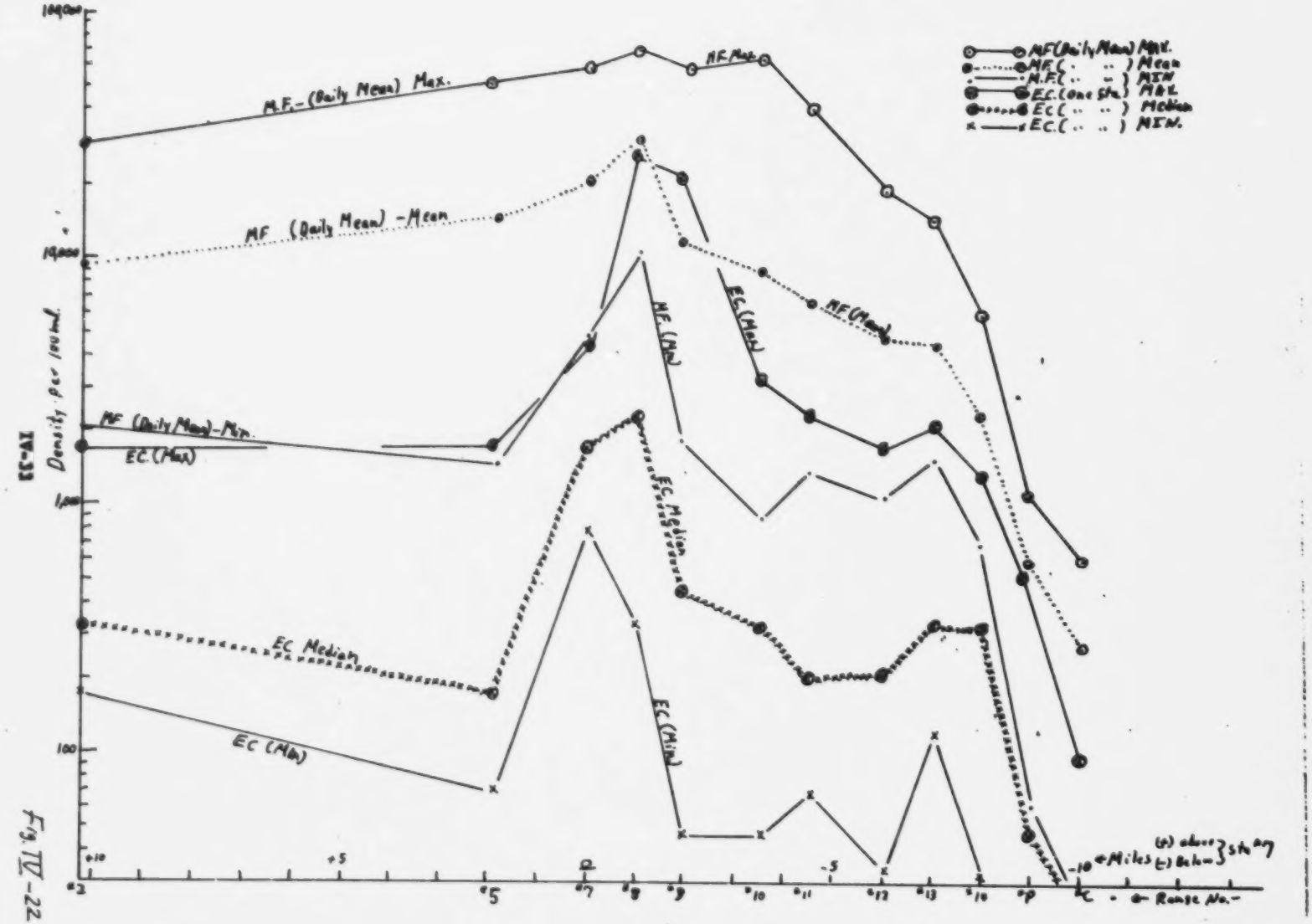

M.F.- (Daily Mean) Max.
MF (Daily Mean) - Mean
MF (Daily Mean) - Min.
EC (Max)
EC Median
EC (Min)
MF (Max)
MF (Mean)
MF (Min)
EC (Max)
EC Median
EC (Min)
MF (Daily Mean) Max.
MF (.. ..) Mean
MF (.. ..) Min
E.C. (One Stn.) Max.
EC (.. ..) Median
EC (.. ..) Min.
Density per 100 sq. mile
(+) above
(-) Below
Miles
Range No.

Fig. IV-22

CHAPTER V

POLLUTION ABATEMENT CONSIDERATIONS

Prediction methods, based upon extensive extrapolation of limited data, are at best very, very crude and this should be fully recognized in the following discussion as it applies to conditions in the St. Croix estuary. Still there is some information upon which an answer regarding the probable effects of varying levels of sewage treatment on shellfish sanitation may be based.

Chlorinated - Biologically Treated - Sanitary Sewage

An analysis of the data for the St. Croix estuary reveals that the sewer systems serving all the communities would have to be limited strictly to sanitary sewage and that this sewage would have to receive the maximum in treatment if the major potential shellfish area were to be classified as acceptable for market shellfishing. The crude analysis upon which this conclusion is based is given in Figure V-1.

Since some of the pollution sources discharge directly into the tidal portion of the river-estuary system it is difficult to determine present contributions without a study of the outfall loadings both bacteriological and flow. In the river portion the EC test has been considered as the more reliable indicator and accordingly an analysis of population loadings has been based upon this as is shown in item #1 of Figure V-1. Range #7 is at the head of the estuary but has been assumed to be composed mostly of river water for this comparison. On the basis of this calculation it would appear that Range #7 represents a population contribution of approximately 7,000. The estimated total contribution for the same location is about 10,000 so that the levels of pollution at Range #7 are considered as representing seven-tenths of the total. The remainder of the pollution being discharged in the estuary portions below Range #7 where it is mixed with sea water and so changed that a population equivalent evaluation is not possible.

Item #3 of Figure V-1 compares the Range #7 values, increased by 30%, with the results at Range #C for the average conditions and for the heavy rainfall situations. Range #C has been selected as that which represents the desirable boundary for any favorable classification of the major potential shellfish producing area in the estuary. Based upon this analysis it is seen that the receiving waters between the two ranges is about 98% efficient as a pollution abatement method. It is not known now or if this efficiency might be affected by temperature changes or changes in the rainfall or run-off that are the expected variations from those for the period of study.

In item #4 of Figure V-1 the calculations are based upon the 98% efficiency and two other lesser efficiencies which might be all that should be relied upon for any extended period of area approval. The MF data is utilized for this analysis since it has been considered equally representative as an indicator and the data is more extensive in coverage and quantity. Starting out with a requirement of 70 per 100ml for Range #C we can estimate what pollution loadings might be acceptable at Range #7, assuming that the sewage plant outfall would be near this location. The first calculation is then based upon the assumption that only sanitary sewage would be treated and thus the 50% condition, as determined by the study, has been selected as representing this situation where only sanitary wastes are contained in the sewers. A high degree of treatment is seen to be needed.

The next consideration would be that of an interceptor taking in the existing combined sewers. This is considered from the point of view of the amount of sewage that may be by-passed from the interceptor with an associated treatment of that reaching the sewage plant of 95% and 98%. Since this sewage would represent the flushing and other conditions associated with the peak findings during the study, at least, an 80,000 MF value for raw conditions at Range #7 has been utilized for this comparison. It is seen that for 95% treatment of the sewage reaching the plant none of the sewage could be by-passed at such times of rainfall and sewer flushing. At 98% treatment during such conditions, again practically none should be by-passed if the area in Range #C is to be continuously acceptable.

The last consideration is that of a by-pass from a separate sanitary sewer system. This might result from pumping station failure for short periods of time. The same might be considered in terms of other interruptions of sewage treatment such as short term chlorination interruption. It may be seen that even at the best of conditions in the receiving waters only limited by-passing or treatment interruptions would be permitted without a change in area classification at Range #C.

This last consideration may also indicate that if the most unfavorable conditions during the high rainfall in the fall or during the high run-off or adverse temperature conditions in the spring did not exceed these levels the shellfish area would be protected. If later studies indicated that these conditions resulted in more adverse conditions then this would give some indication of the time that the area would not be available for direct marketing as a part of the conditional area determination.

In conclusion it may be stated that if the area of greatest potential for shellfishing in the St. Croix estuary, Oak Bay, is to be available, then all the communities and industries contributing sanitary sewage from the Grand Falls area downstream would have to provide for collection of the sewage in separate sanitary sewers for all of the domestic wastes and this sewage would have to be given treatment equivalent to secondary treatment and chlorination. If anything less is given present indications are that the shellfish area would not be acceptable even on condition. At best, the area would be classified as a Conditionally Approved area and thus would require the extensive prior to classification survey and conditional operating requirements associated with such a classification.

Comments

There are several items that might be studied, such as the quantity and quality of the sewage outfalls, the conditions during high rainfall seasons and high run-off and most unfavorable temperature conditions. However, considering the crudeness of present prediction methods it does not seem advisable to recommend that they have to be conducted before arriving at a decision as to pollution abatement needs.

SEWAGE TREATMENT NEEDS -- ST. CROIX AND ESTUARY TO PROTECT OAK BAY

1. **Population Contribution Considerations:** EC+ - best indicator fresh water portion.

   Use: (a) Daily Coliform Contribution = 100×10^9 (Furfari and Kittrell)
   (b) EC+ = 1/10 of Coliform = $10 \times 10^9 = 10^{10}$
   (c) 1 Cubic Foot = 28.3x10 (100ml units)
   (d) Qcfs - St. Croix = 1,500
   (e) ∴PE = 3.7xEC+(value)

   Results:

Range	50% Value	PE	90% Value	PE	Remarks
2	480	1,776	1,600	5,960	Pulp mill at Woodland, Me.
5	180	666	1,200	4,440	Milltown, Me. (International Bridge)
7	1,900	7,030	4,200	15,540	Calais, Me. (International Bridge)

2. **Pollution Source Contributions:**

Place	Pop. Est.	Remarks
Princeton, Me.	200	Pg.12 Manuscript 63-1 -- "On the basis of ... the median coliform content observed at Range 2 must be attributed largely to sanitary wastes from the St. Croix Paper Company mill, since outfalls from the Town of Woodland, Me., are located downstream from Range 2."
Woodland, Me.	1,200	
Calais, Me.	4,000*	
Milltown, N.B.	2,000*	
St. Stephen, N.B.	3,400*	
*Population Ranges 5→9 = 9,400 (use 10,000)		

∴Since at Range #7 the PE is 7,000 while total for area is 10,000 the Range #7 is considered to represent 7/10 of total for area.

3. **Treatment Efficiency of Estuary - Between Range 7 and Range C:**

	MF Results				EC Results			
	Range #7		Range C		Range #7		Range C	
Remarks	MF	Plus .30xMF	50%MF	% Eff.	EC	Plus .30EC	EC	% Eff.
50% Value-- Aver. Cond.	16,500	21,000	250	98	1,900	2,500	15	99
Most Unfavorable Cond. Fig. IV-21	58,000	75,000	590	98	3,400	4,420	78	98

Efficiency based on Range 7 value increased by 30% to account for outlets downstream.

FIGURE V-1

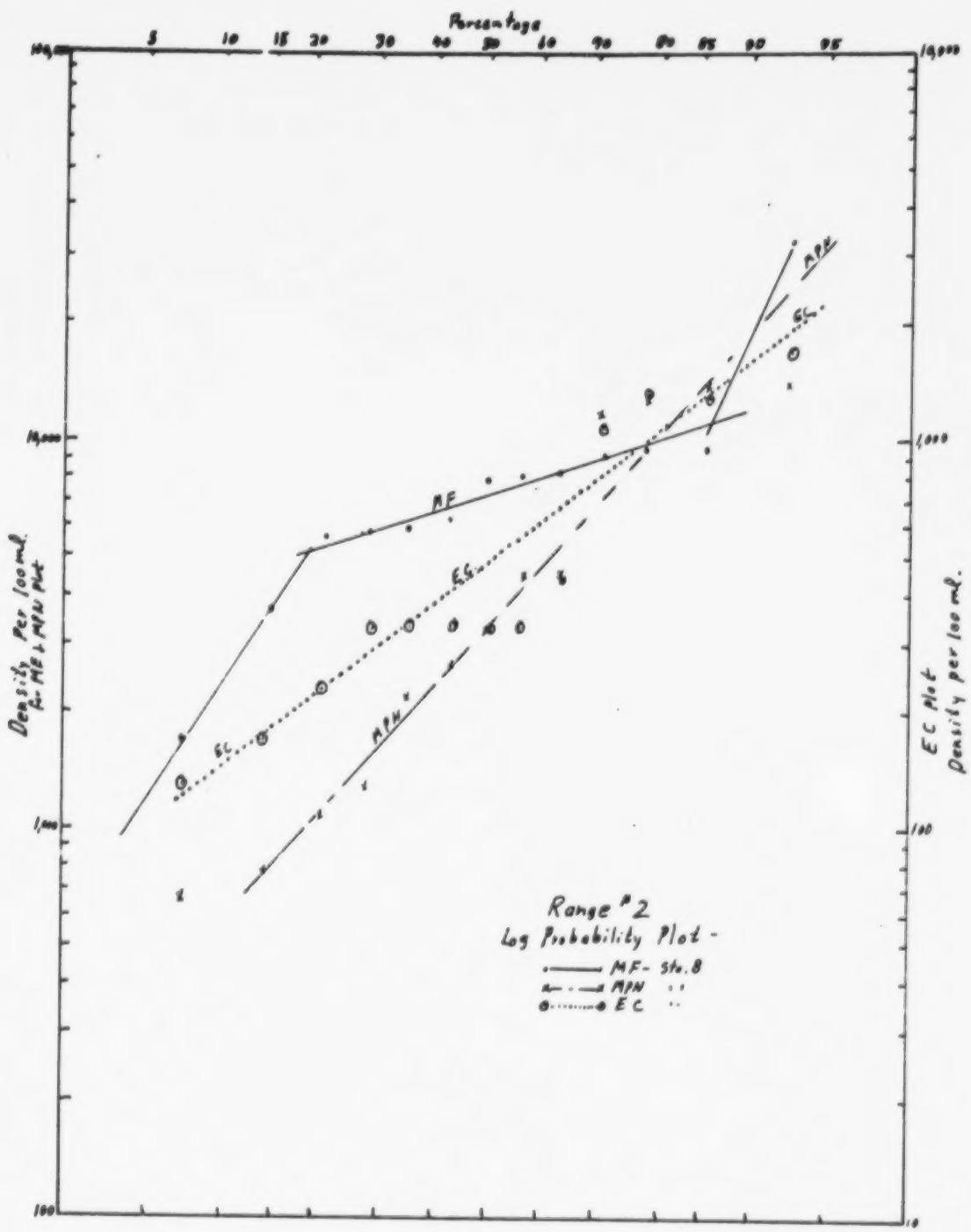
SEWAGE TREATMENT NEEDS (Continued)

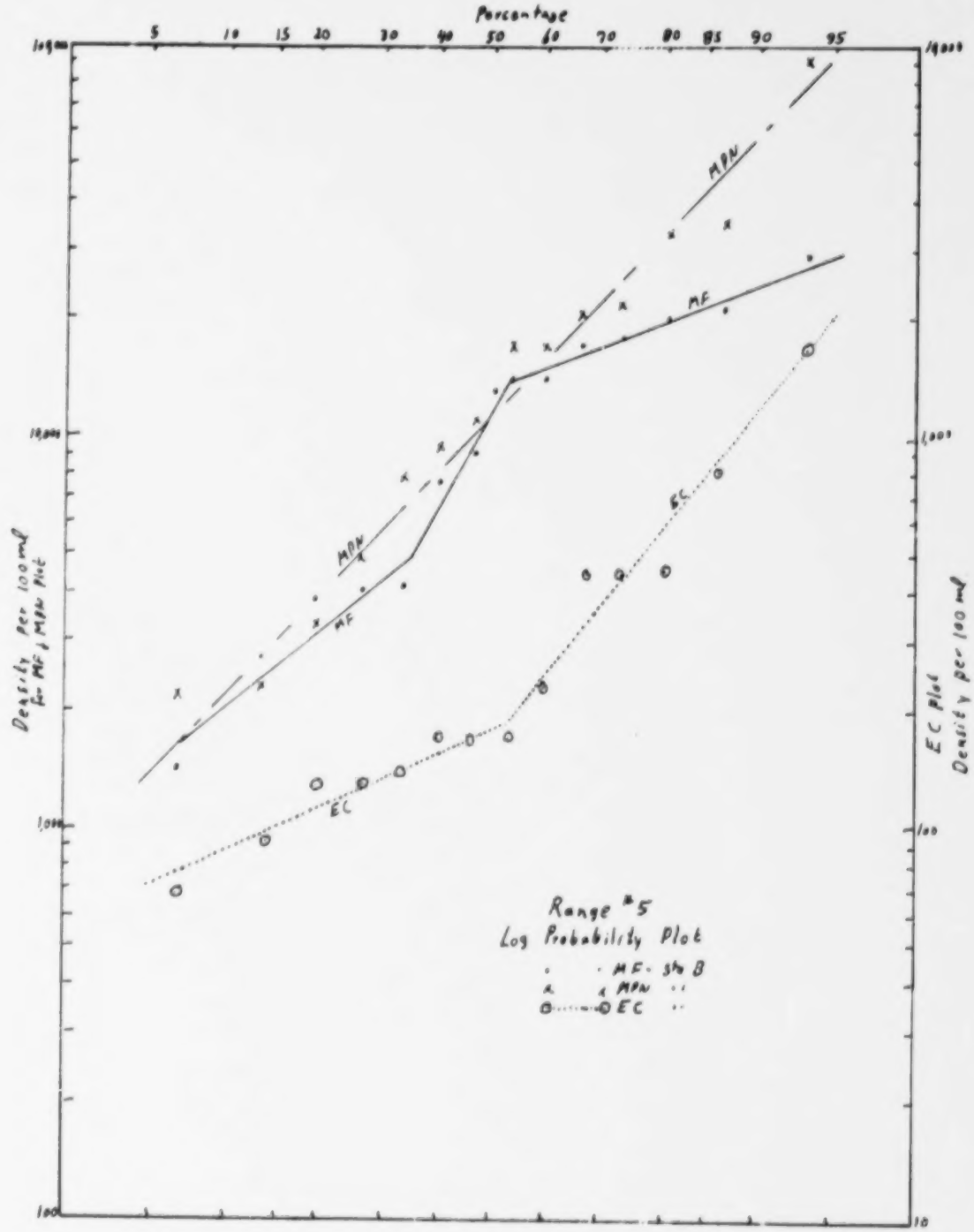
4. Treatment Needs of Contributory Sewage Sources:

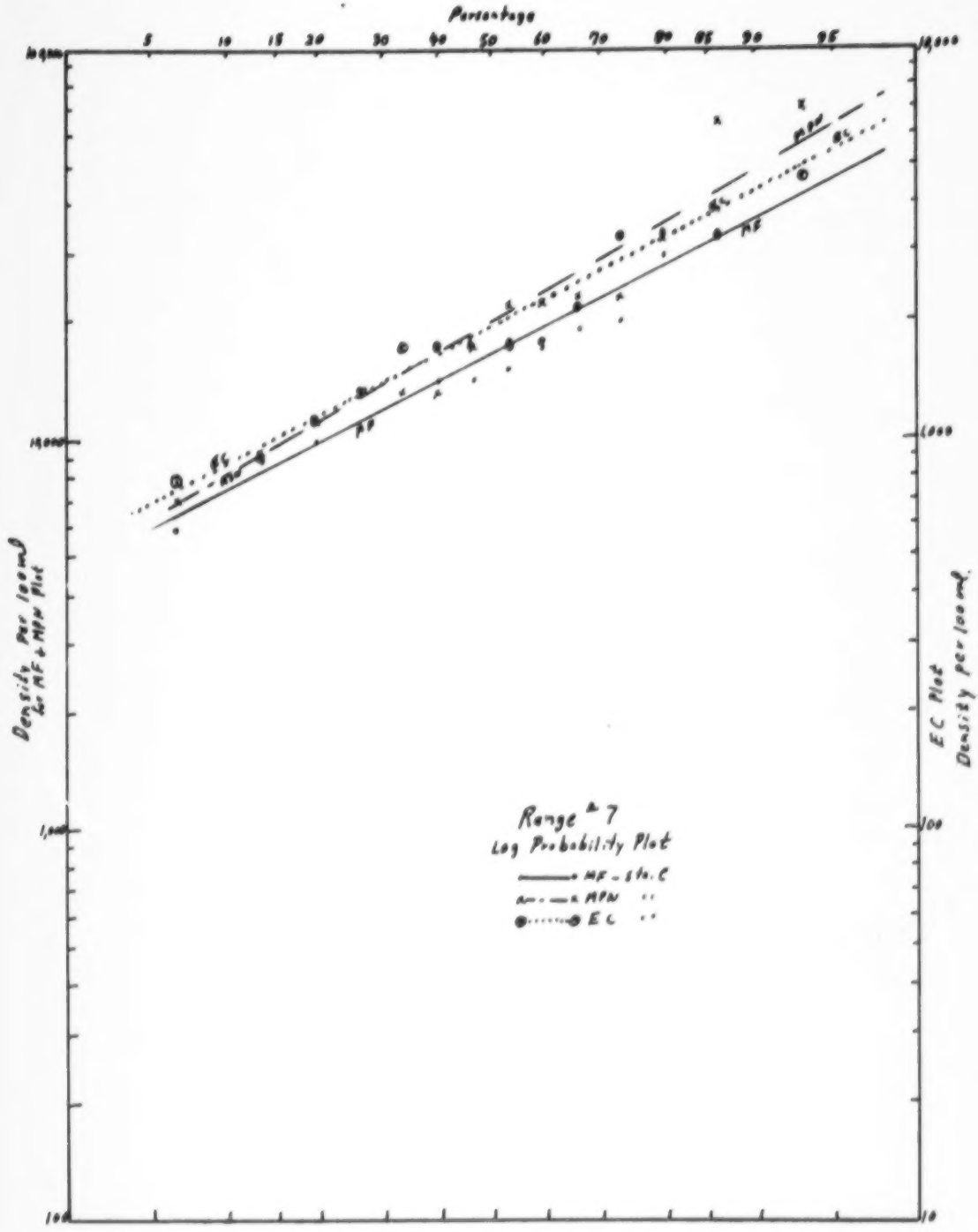
Required: 70 MPN at Range "C" (Most Unfavorable Condition)

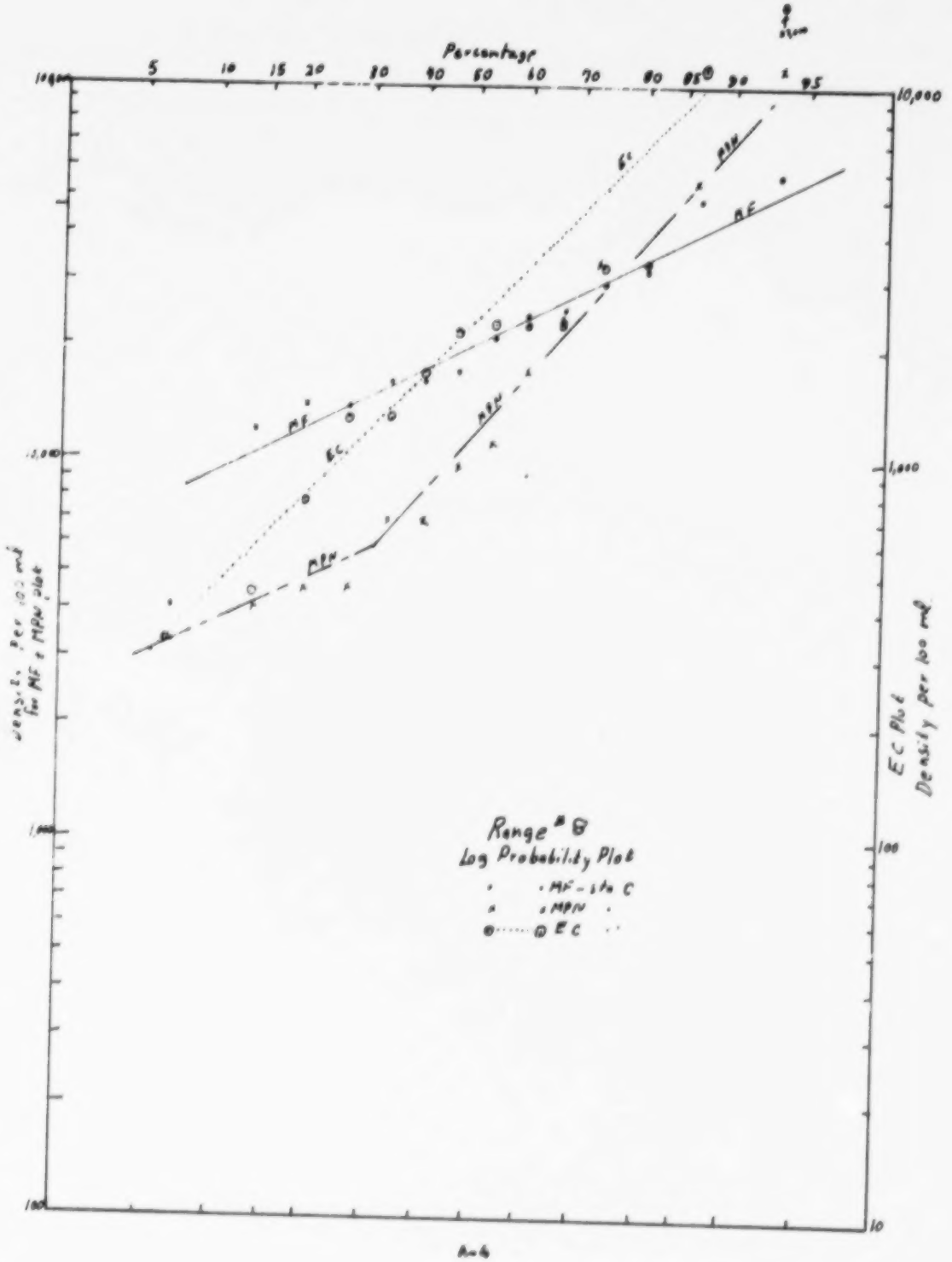
Item	Value	Value	Value
1. Efficiency of Estuary-Range #7 thru C	90%	95%	98%
2. Related Range #7 Value Max. (assume all discharge here)	700	1,400	3,500
3. Separate Sewer System - % Treatment (20,000 MF)	96.5%	93%	82½%
4. Maximum By-Pass - Combined Sewerage - 95% Treated Storm Water 80,000 MF-Range 7	---	---	---
5. Maximum By-Pass - Combined Sewerage - 98% Treated Storm Water 80,000 MF-Range 7	---	---	---
6. Maximum By-Pass - Separate Sewer System (20,000 MF) 98% Treatment	1½%	5%	15%

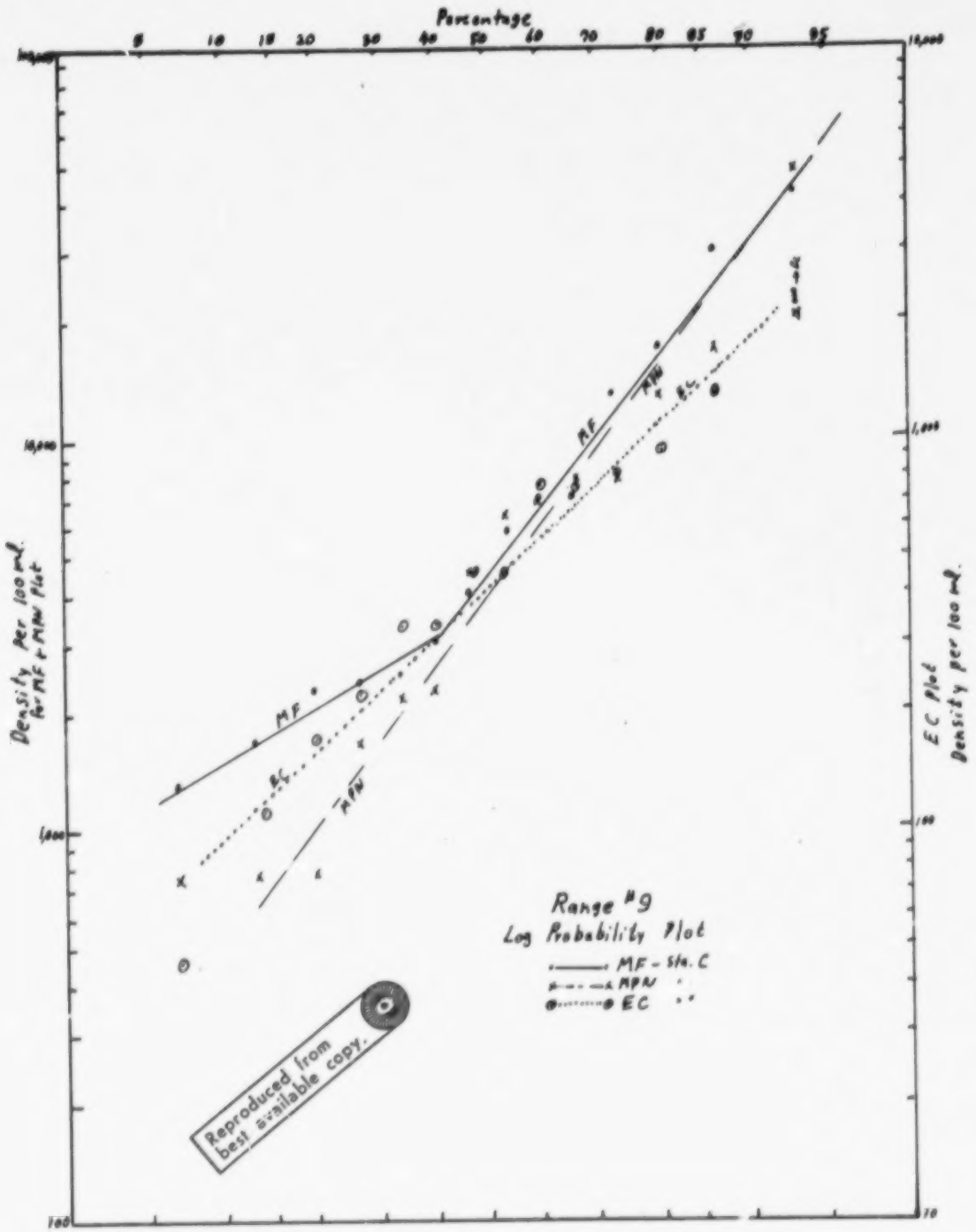
APPENDIX


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
10
MF
EC
APH
Density Per 100 ml. for MF & APH Plot
EC Plot Density per 100 ml.
Range #2
Log Probability Plot -
MF - Sta. 8
APH "
EC "


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
MPN
MF
EC
Density per 100 ml for MF & MPN Plot
EC Plot
Density per 100 ml
Range #5
Log Probability Plot
MF. Sta B
MPN ..
EC ..


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Density Per 100 ml
for MF & MPN Plot
EC Plot
Density per 100 ml
Range 7
Log Probability Plot
MF - Std. C
MPN "
EC "


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
10
MF
MPN
EC
Density per 100 ml for MF & MPN plot
EC Plot
Density per 100 ml
Range "B"
Log Probability Plot
MF - 44a C
MPN
EC



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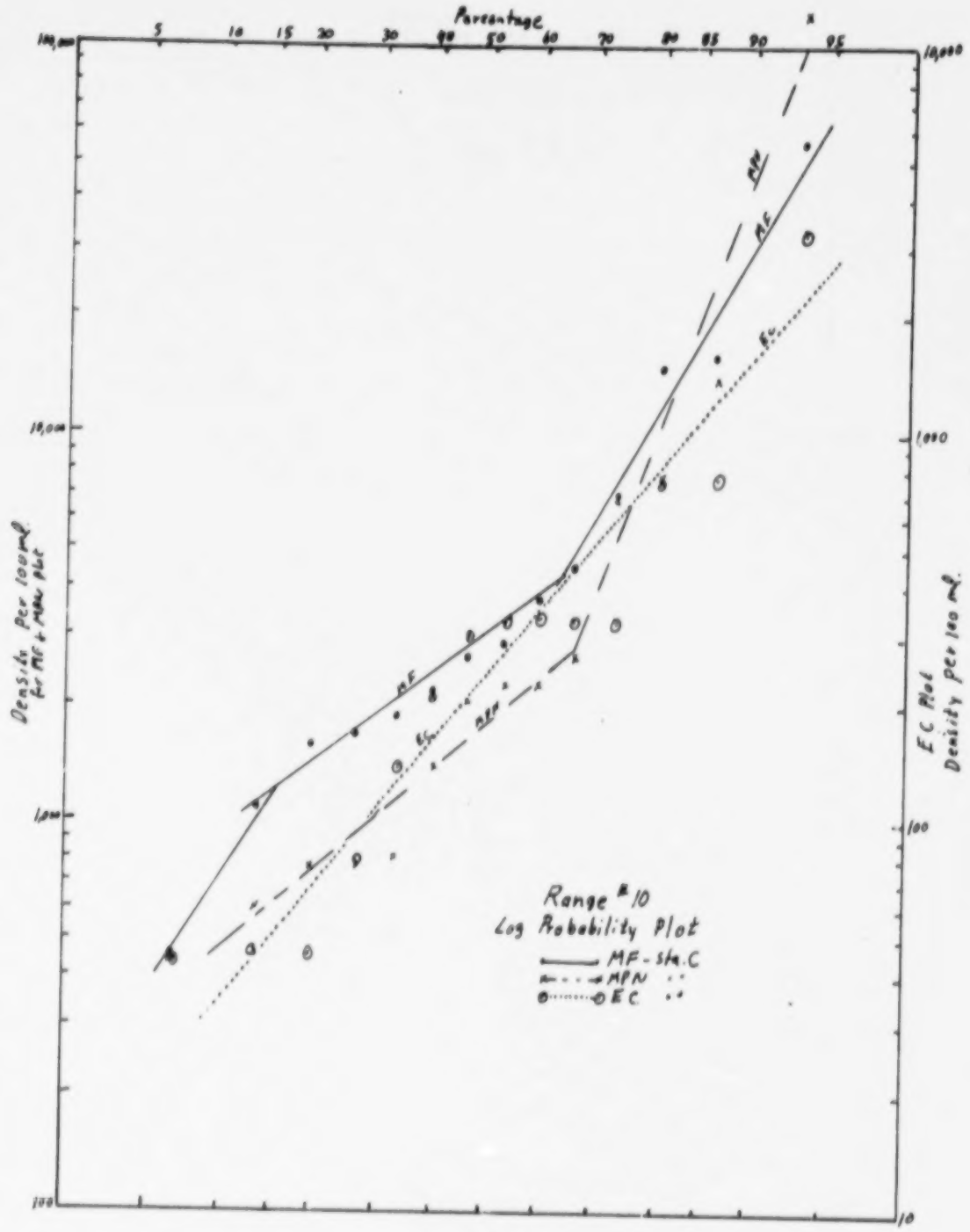
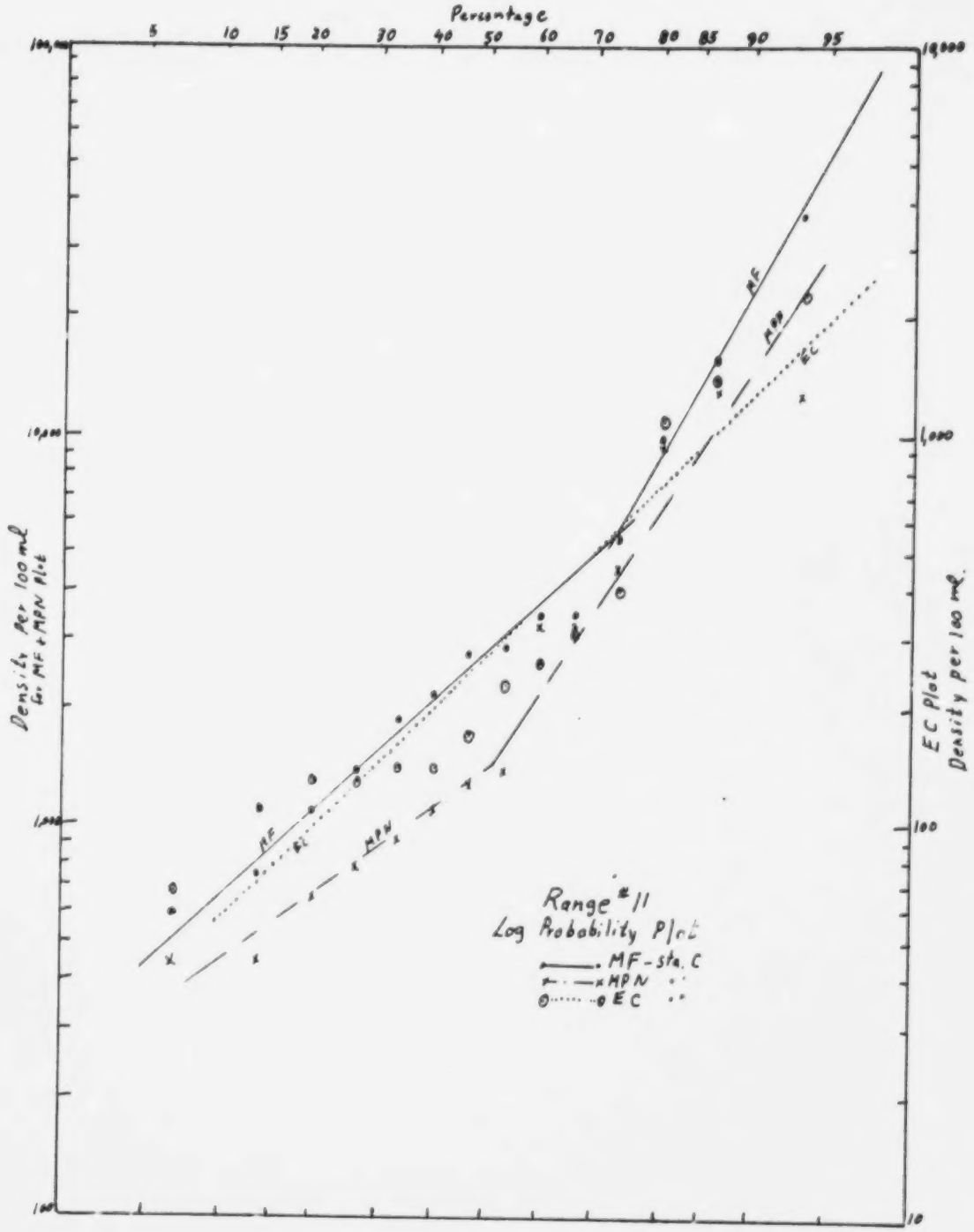
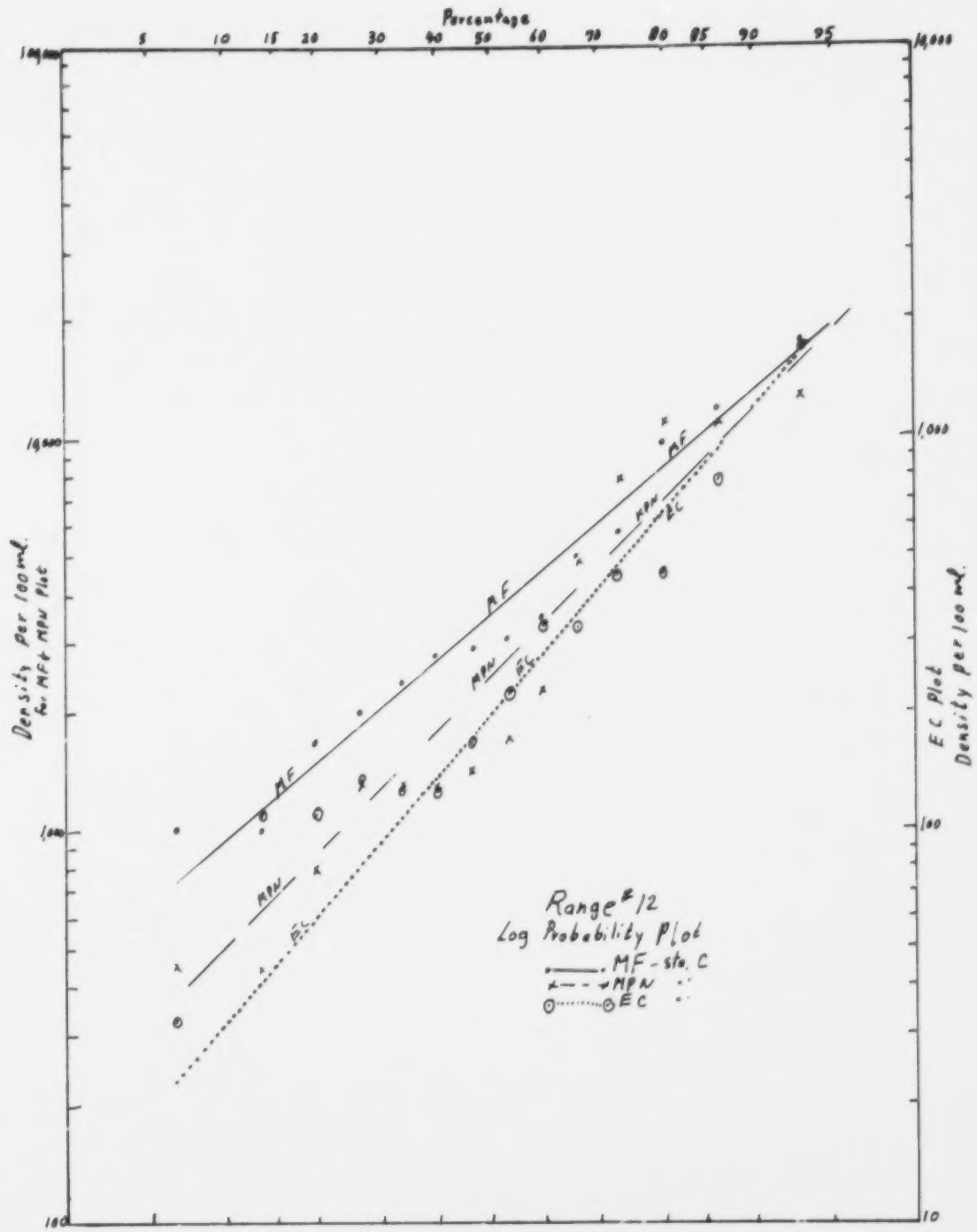
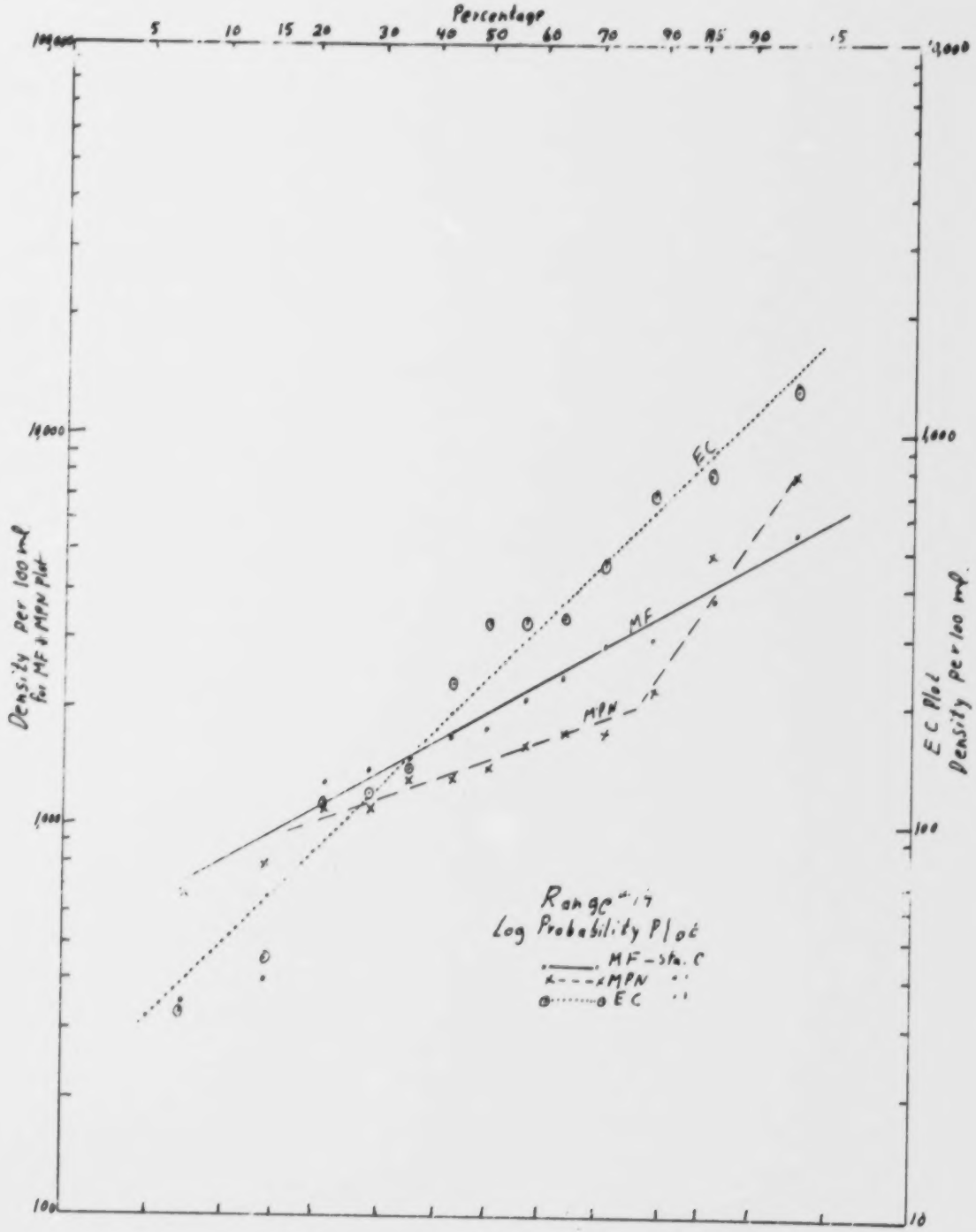
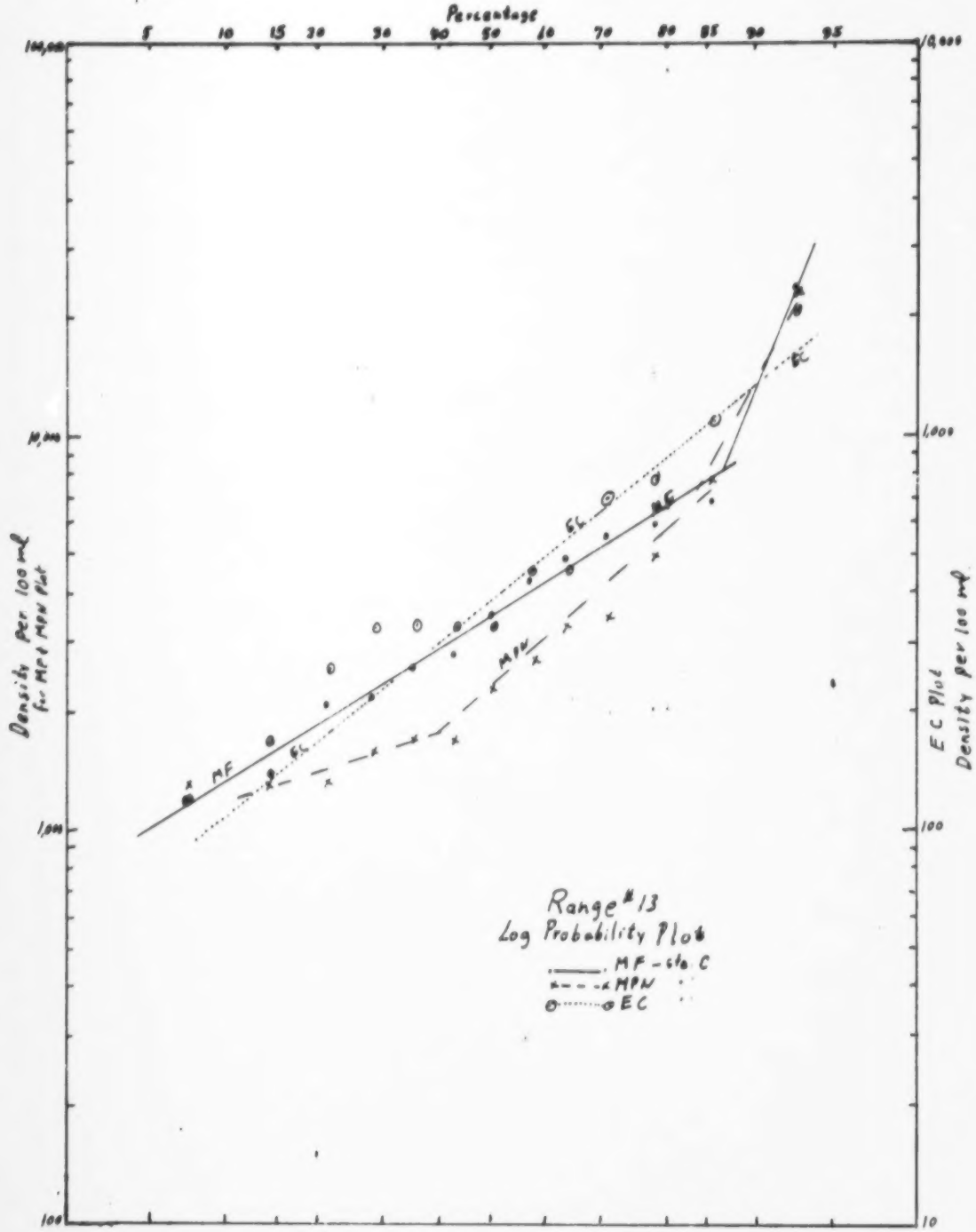
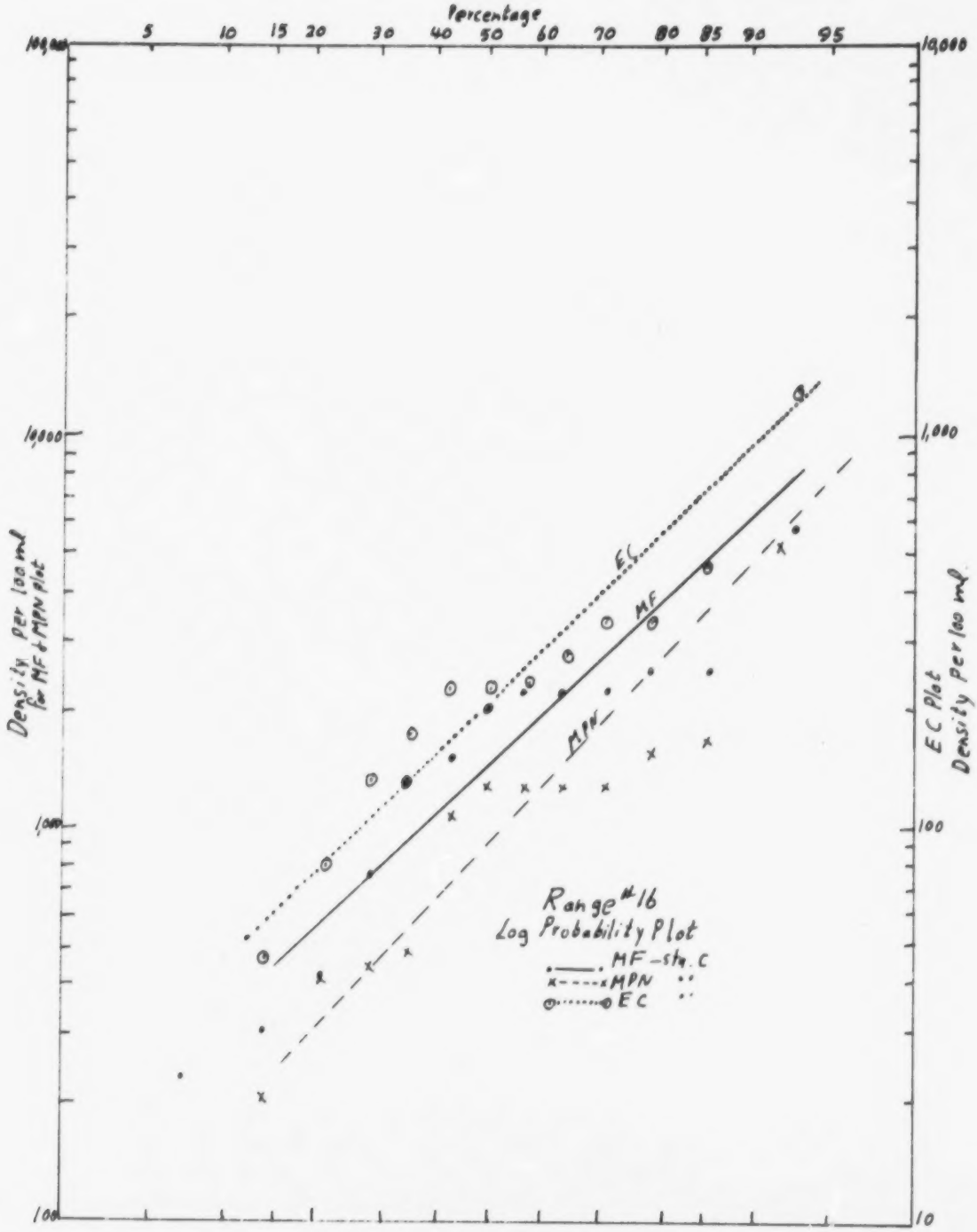

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
100,000
10,000
1,000
100
10
Density Per 100 ml for MF & MPN Plot
EC Plot Density per 100 ml
MF
MPN
Range = 10
Log Probability Plot
MF - Std. C
MPN
EC

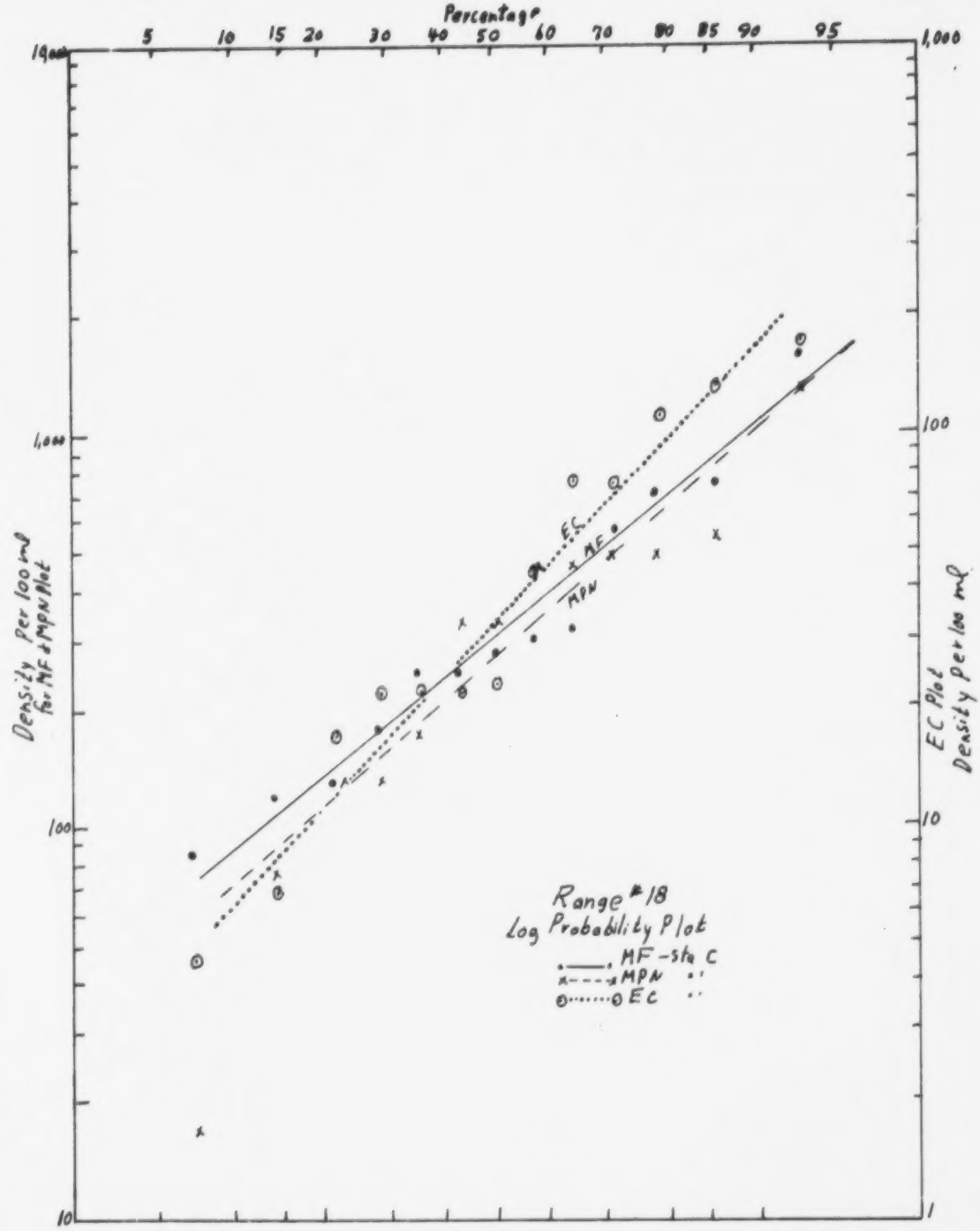

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Density Per 100 ml
Gr. MF + MPN Plot
EC Plot
Density per 100 ml.
1,000
100
10
MF
MPN
EC
Range #11
Log Probability Plot
MF - std. C
MPN
EC

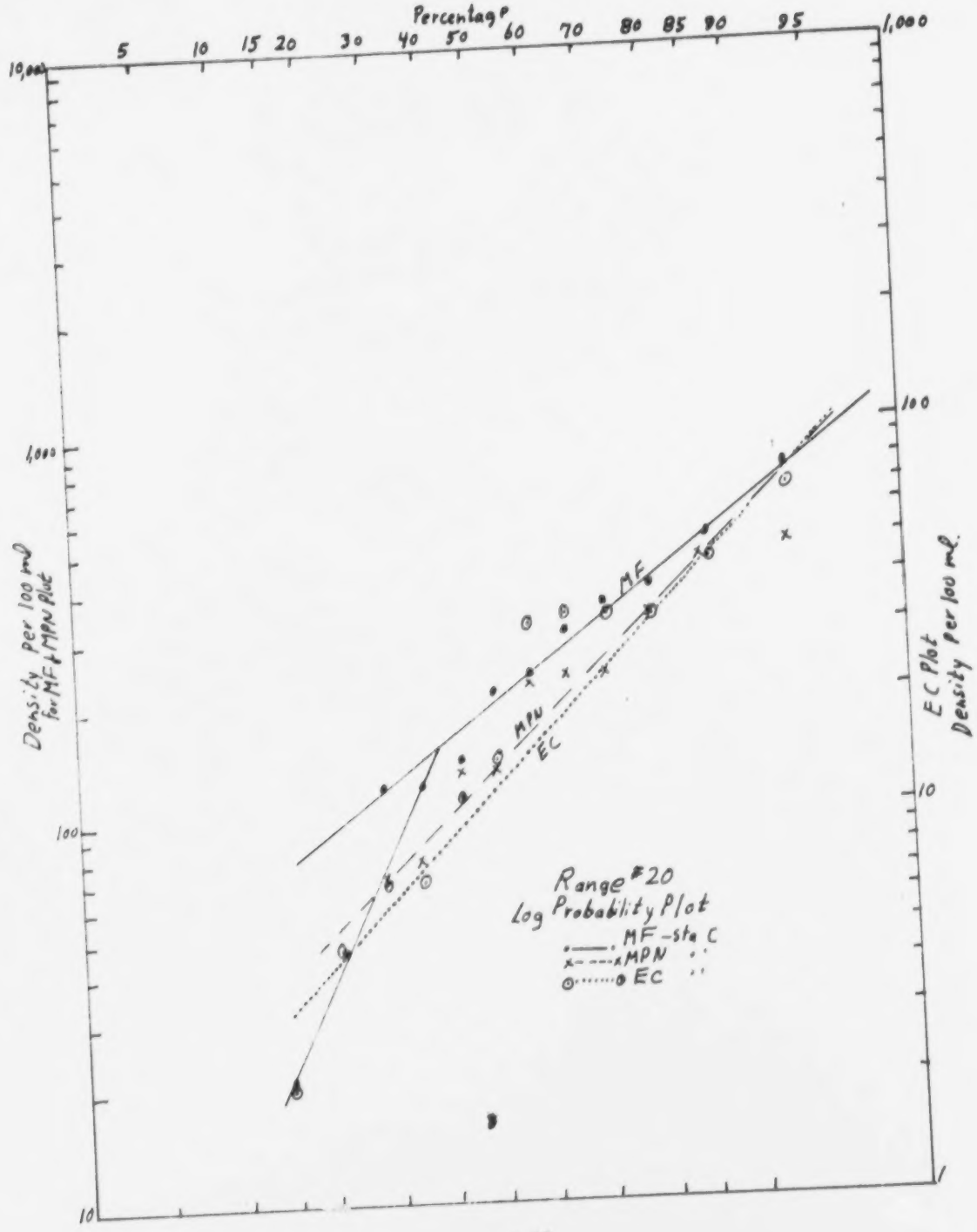

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Density per 100 ml. for MF & MPN Plot
EC Plot Density per 100 ml.
MF
MPN
EC
Range #12
Log Probability Plot
MF - std. C
MPN
EC

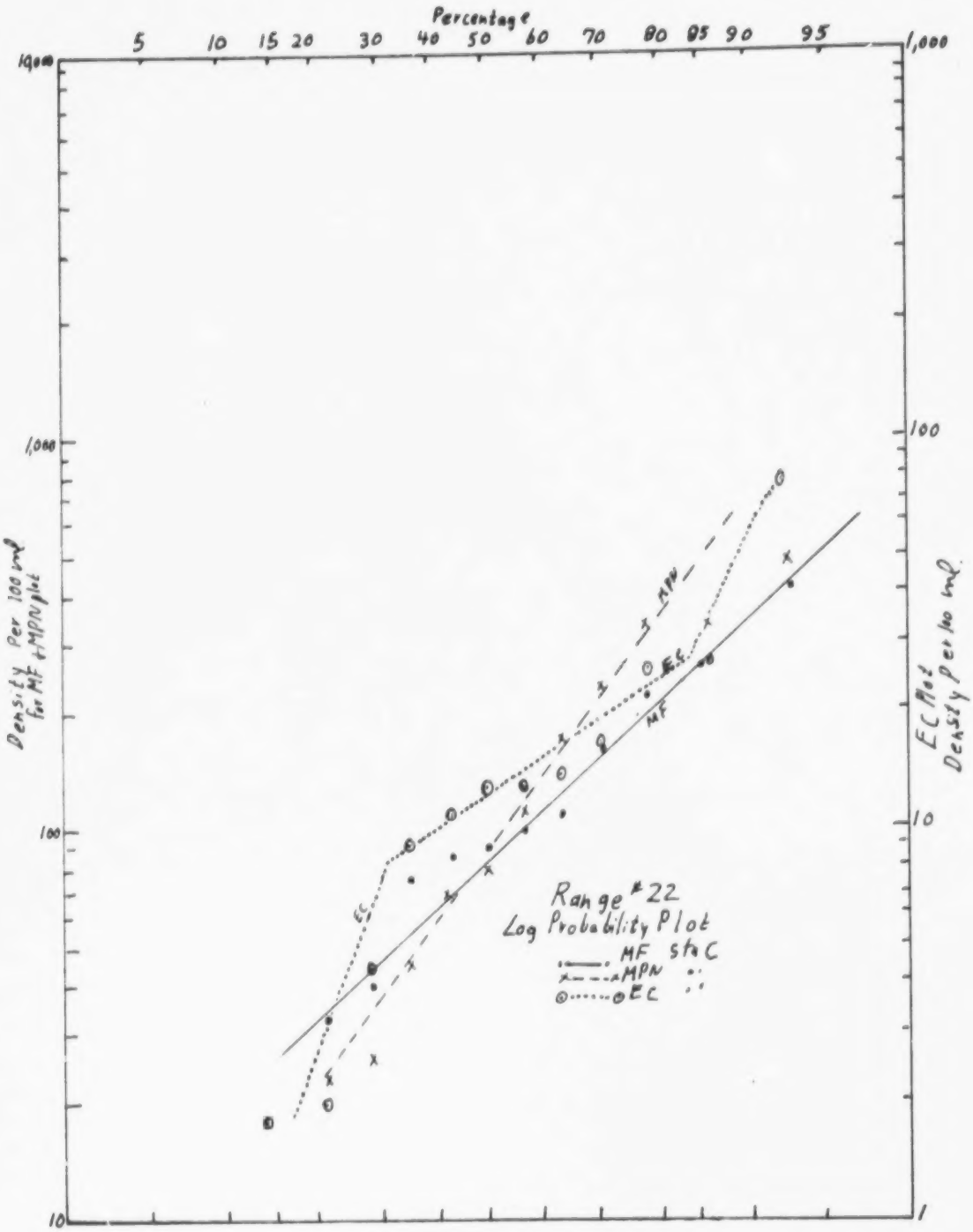

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
10
Density per 100 ml for MF + MPN Plot
EC Plot Density per 100 ml
EC
MF
MPN
Range 4-17
Log Probability Plot
MF - Std. C
MPN
EC

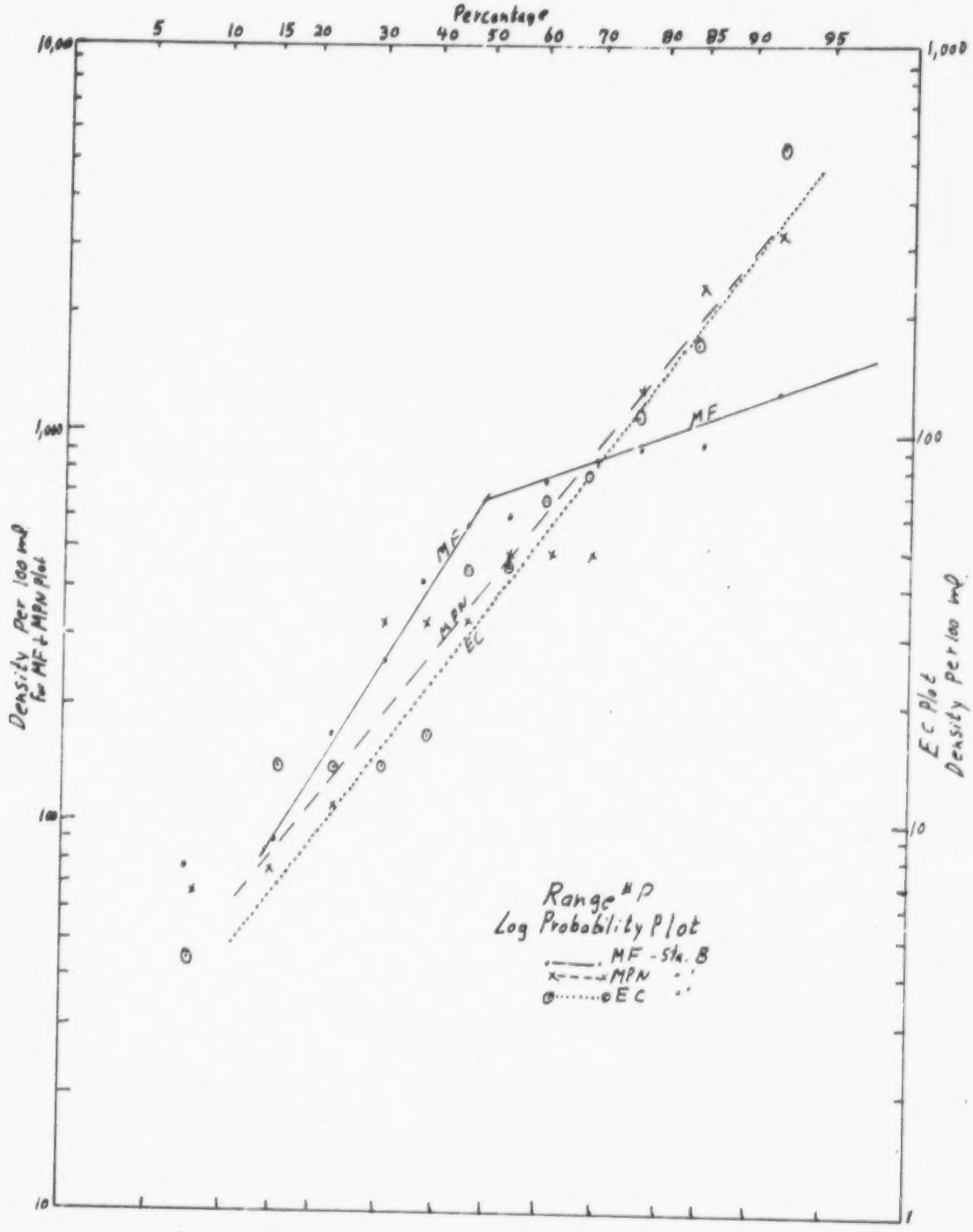

Percentage
5
10
15
20
30
50
70
80
85
90
95
100,000
10,000
1,000
100
10
Density per 100 ml for MPN Plot
EC Plot Density per 100 ml
MF
MPN
EC
Range #13
Log Probability Plot
MF - 44 C
MPN
EC

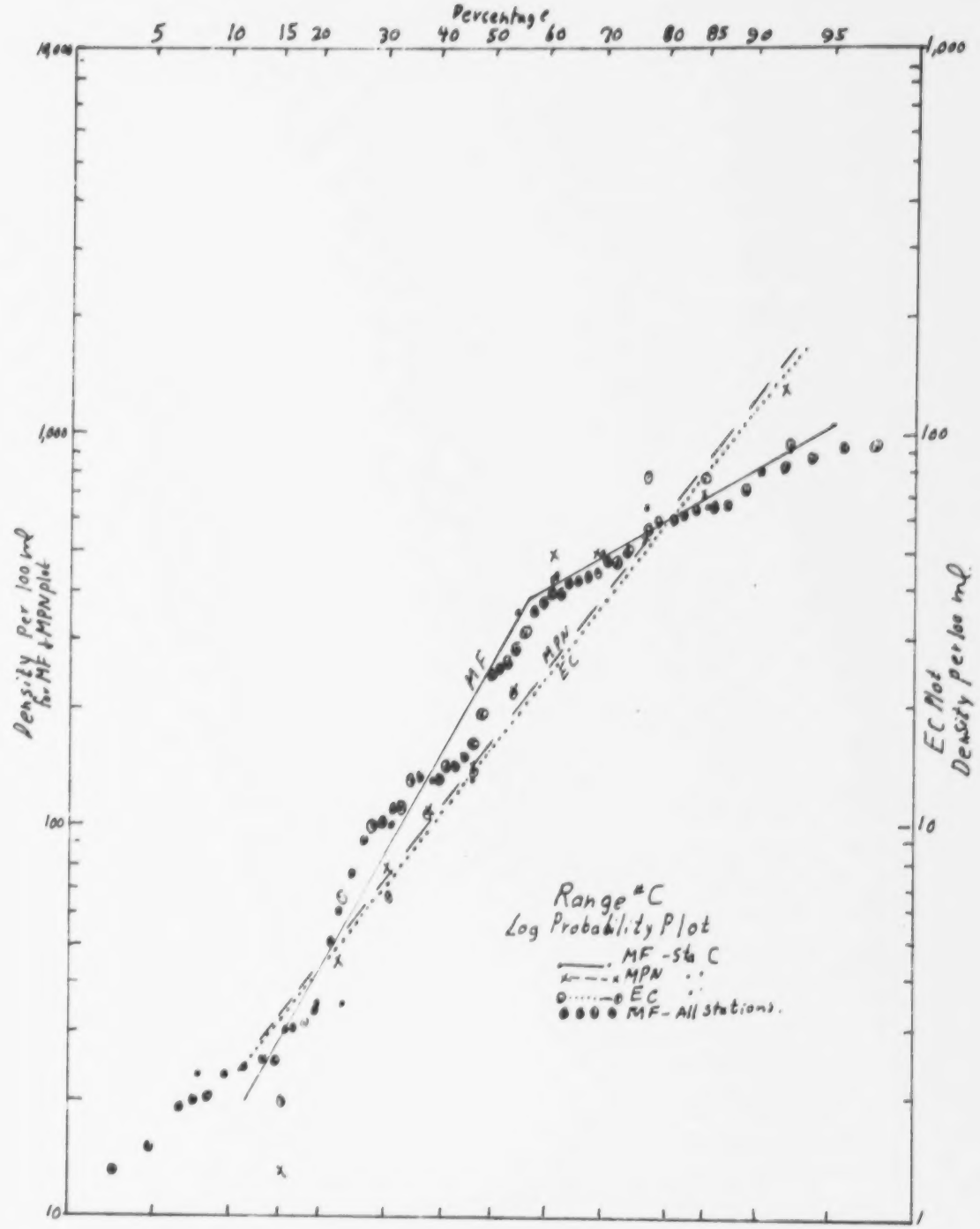

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
10
Density per 100 ml for MF + MPN plot
EC Plot Density per 100 ml
EC
MF
MPN
Range #16
Log Probability Plot
MF - std. C
MPN
EC

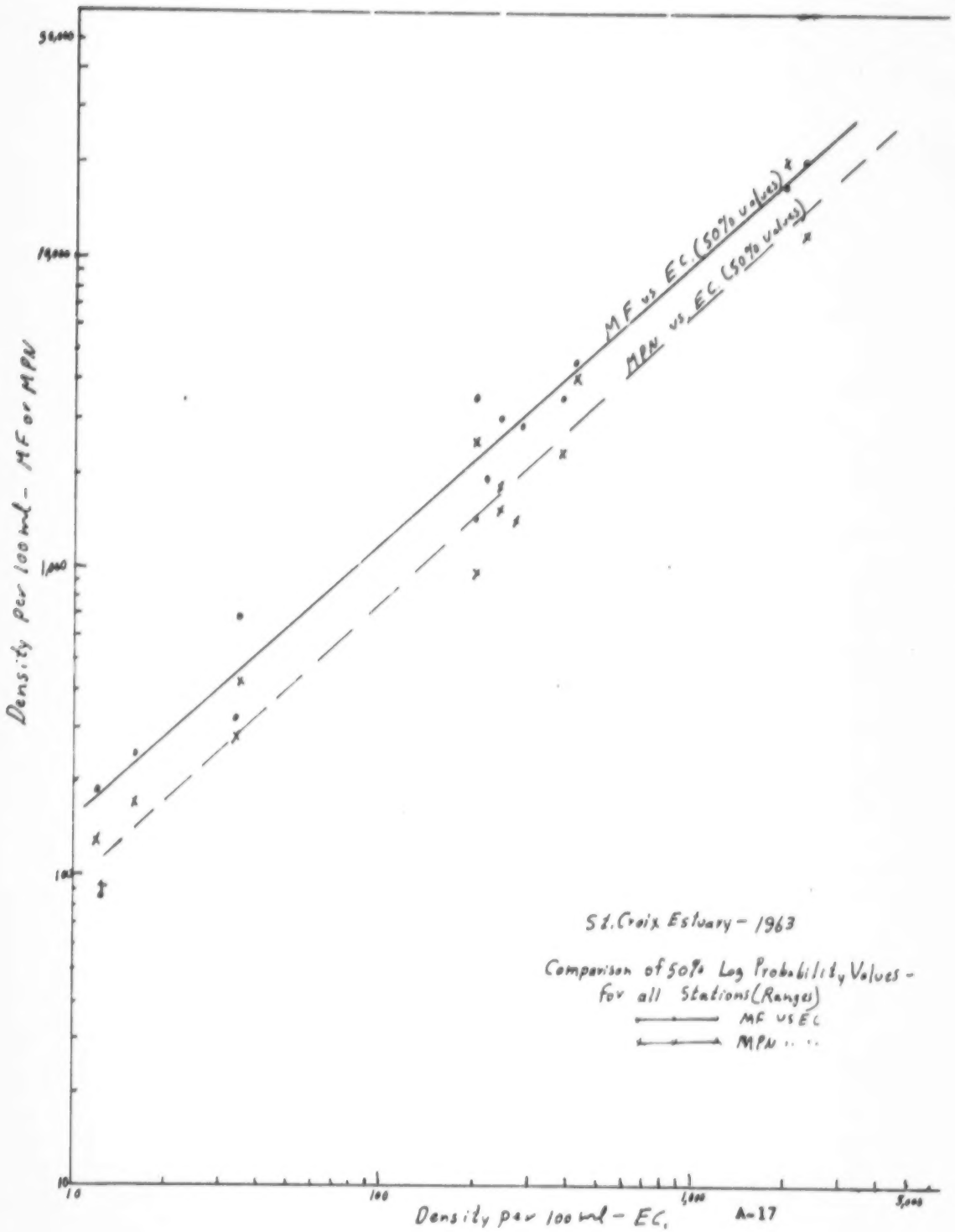

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
1,000
100
10
1
Density Per 100 ml for MF & MPN Plot
EC Plot Density Per 100 ml
EC
MF
MPN
Range #18
Log Probability Plot
MF - Std C
MPN
EC


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
4,000
100
10
1,000
100
10
1
Density Per 100 ml for MF & MPN Plot
EC Plot Density Per 100 ml.
MF
MPN
EC
Range #20
Log Probability Plot
MF - std C
MPN
EC


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
1,000
100
10
1
Density Per 100 ml for MF & MPN plot
EC Mot Density Per 100 ml
MPN
MF
EC
Range #22
Log Probability Plot
MF std C
MPN
EC


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
10
1
Density Per 100 ml for MF + MPN Plot
EC Plot Density Per 100 ml
MF
MPN
EC
Range "P"
Log Probability Plot
MF - Stn. B
MPN
EC


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
1,000
1,000
100
100
10
10
1
Density Per 100 ml for MF & MPN plot
EC Mod Density Per 100 ml
MF
MPN
EC
Range "C
Log Probability Plot
MF - Sta C
MPN
EC
MF - All stations.

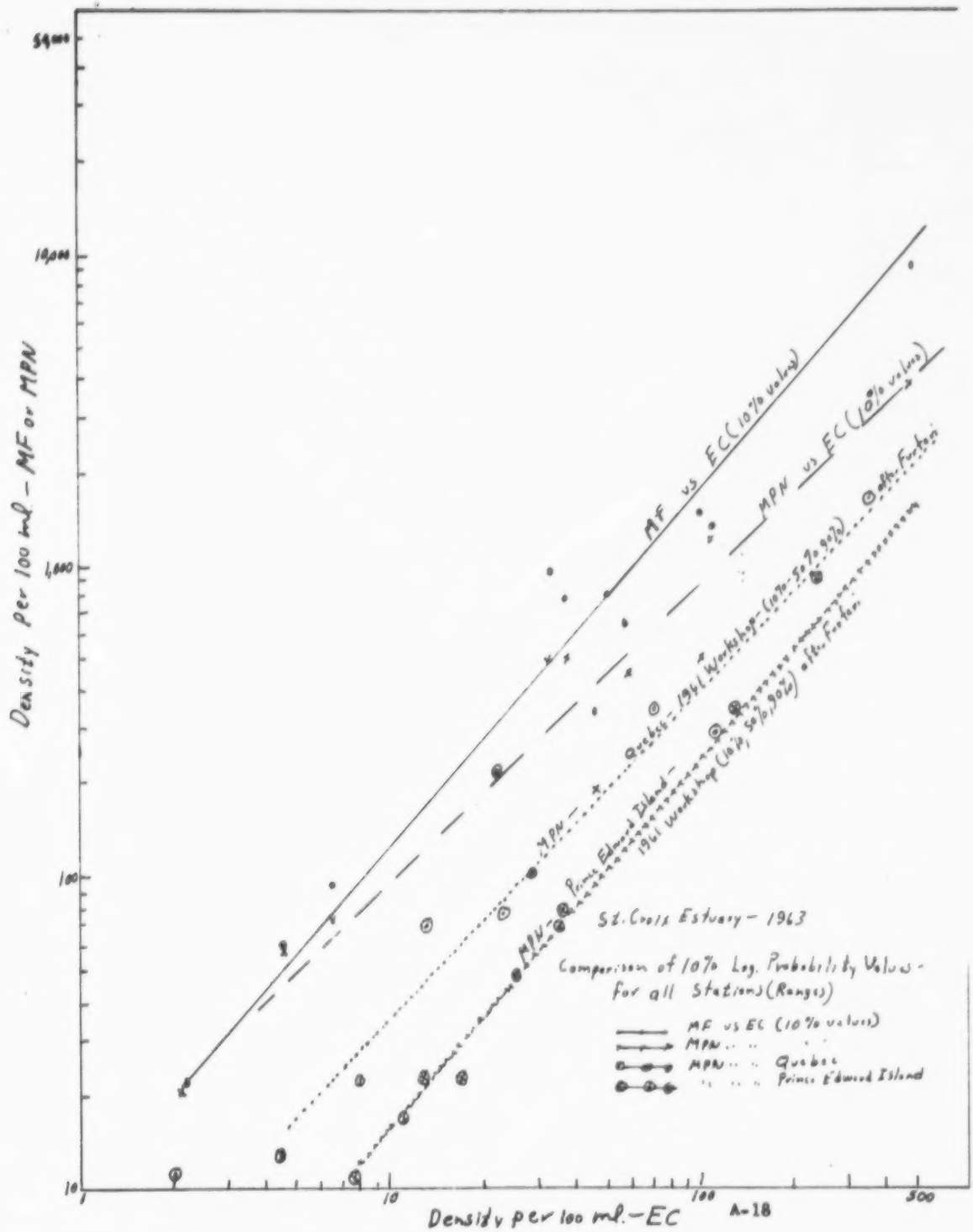


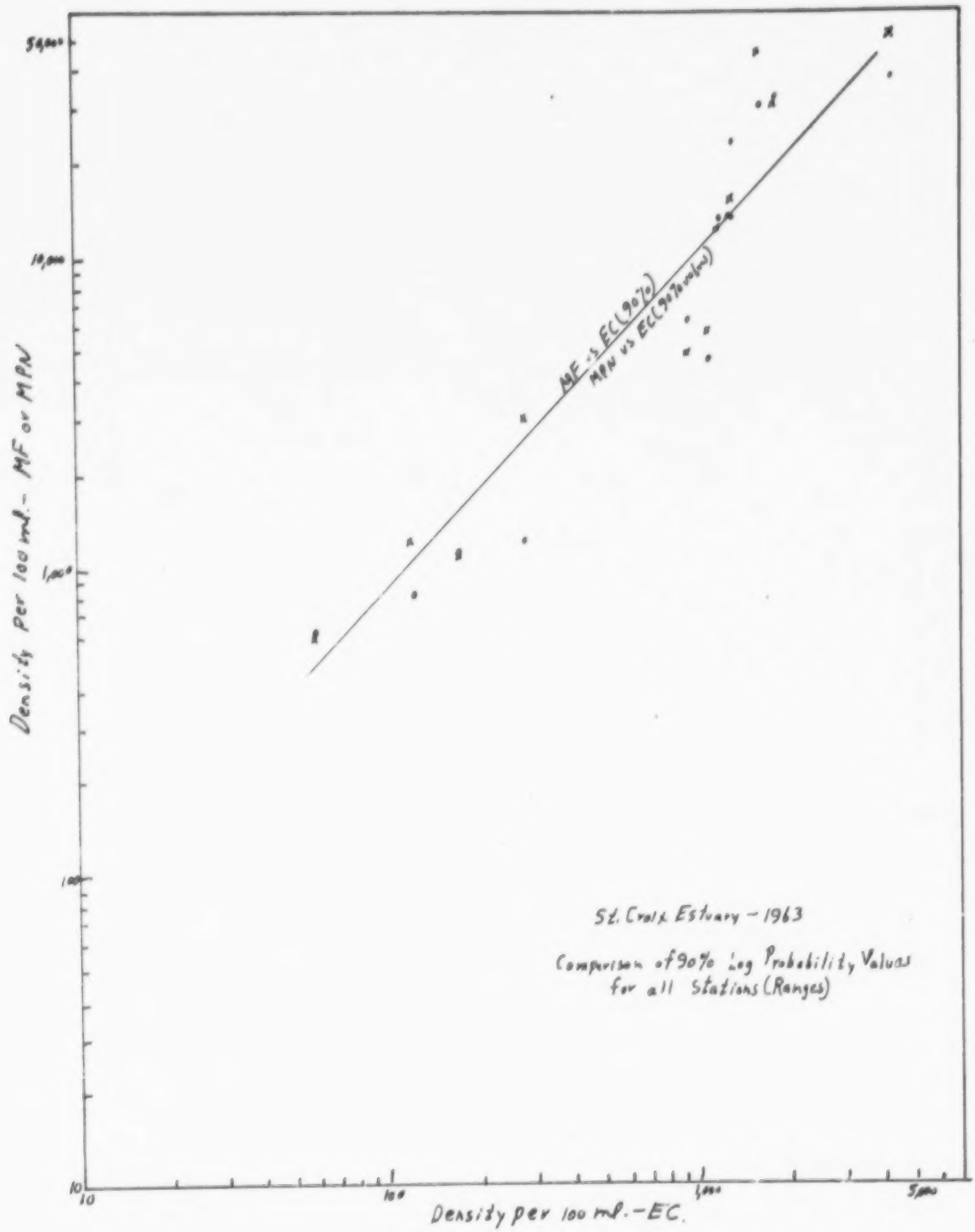
St. Croix Estuary - 1963

Comparison of 50% Log Probability Values - for all Stations (Ranges)

MF vs EC

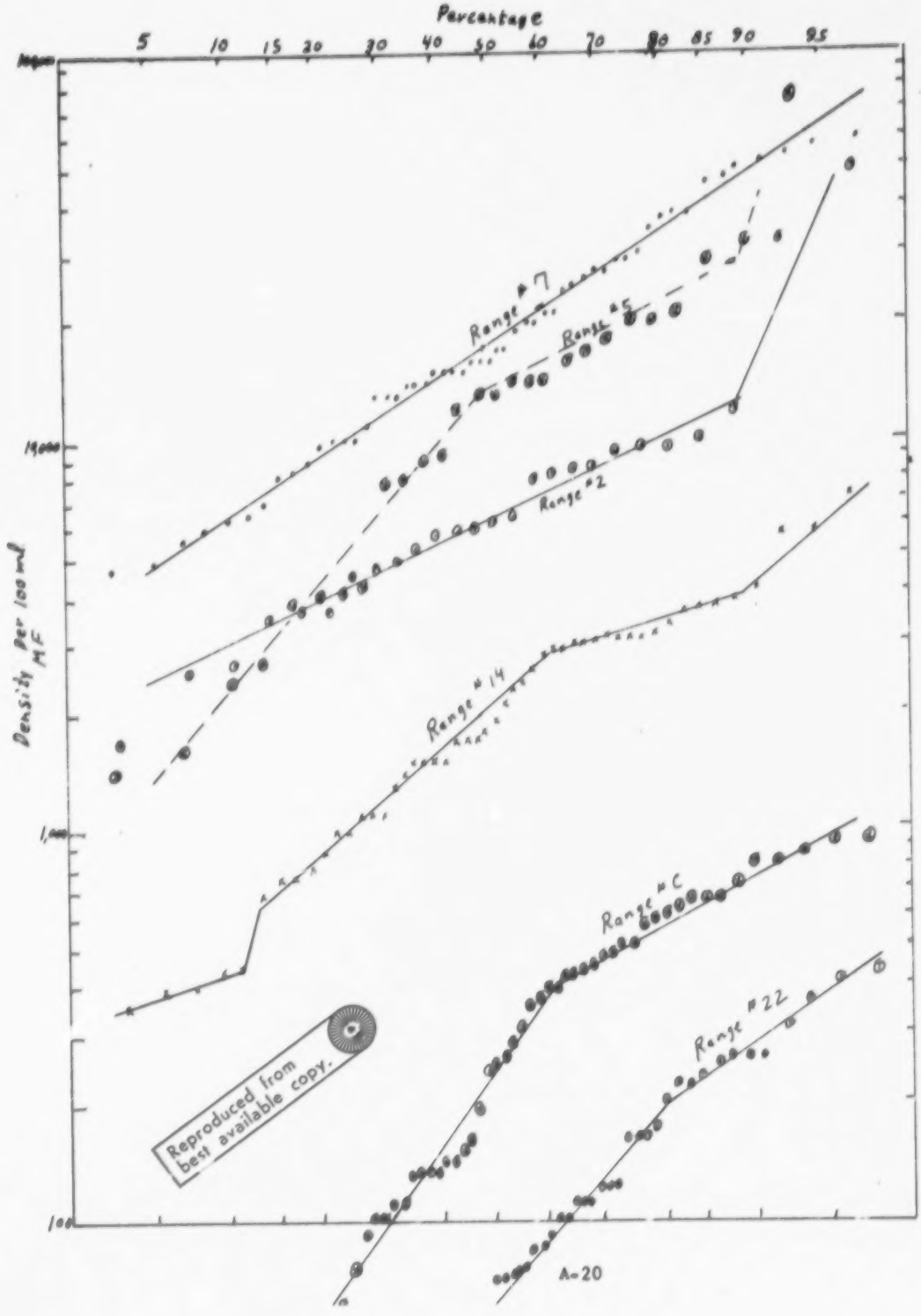
MPN " "


50,000
10,000
1,000
100
10
Density per 100 ml – MF or MPN
MF vs FC (10% values)
MPN vs FC (10% values)
MPN – ×..... Quebec – 1961 Workshop – (10%-50%-90%) after Fenton
MPN – Prince Edward Island – 1961 Workshop (10%, 50%, 90%) after Fenton
St. Croix Estuary – 1963
Comparison of 10% Log. Probability Values – for all Stations (Ranges)
MF vs EC (10% values)
MPN .. ..
MPN .. .. Quebec
.. .. .. Prince Edward Island
1
10
100
500
Density per 100 ml. – EC



St. Croix Estuary - 1963

Comparison of 90% Log Probability Values for all Stations (Ranges)


Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
Density Per 100 mil
Range #7
Range #5
Range #2
Range #14
Range #C
Range #22
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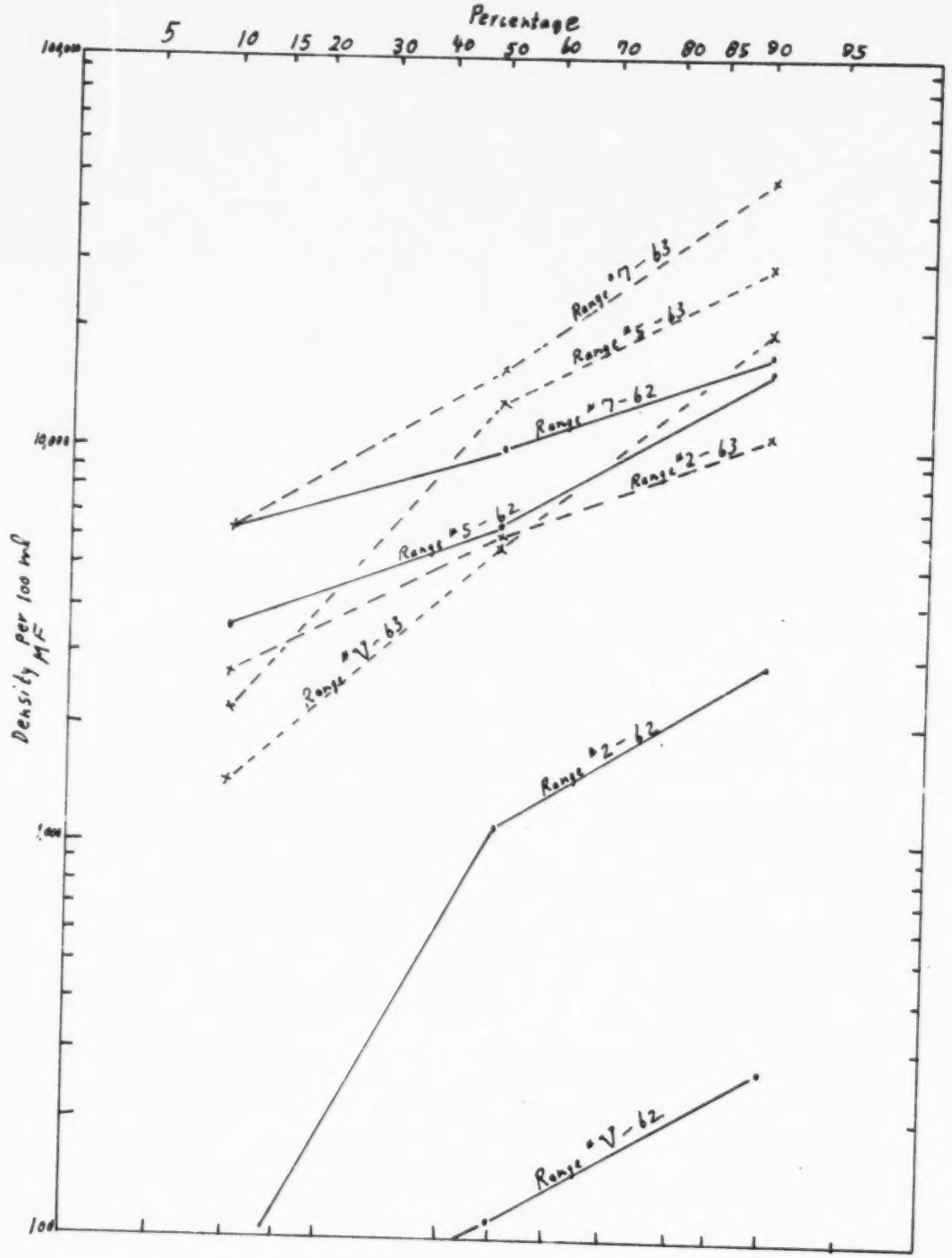
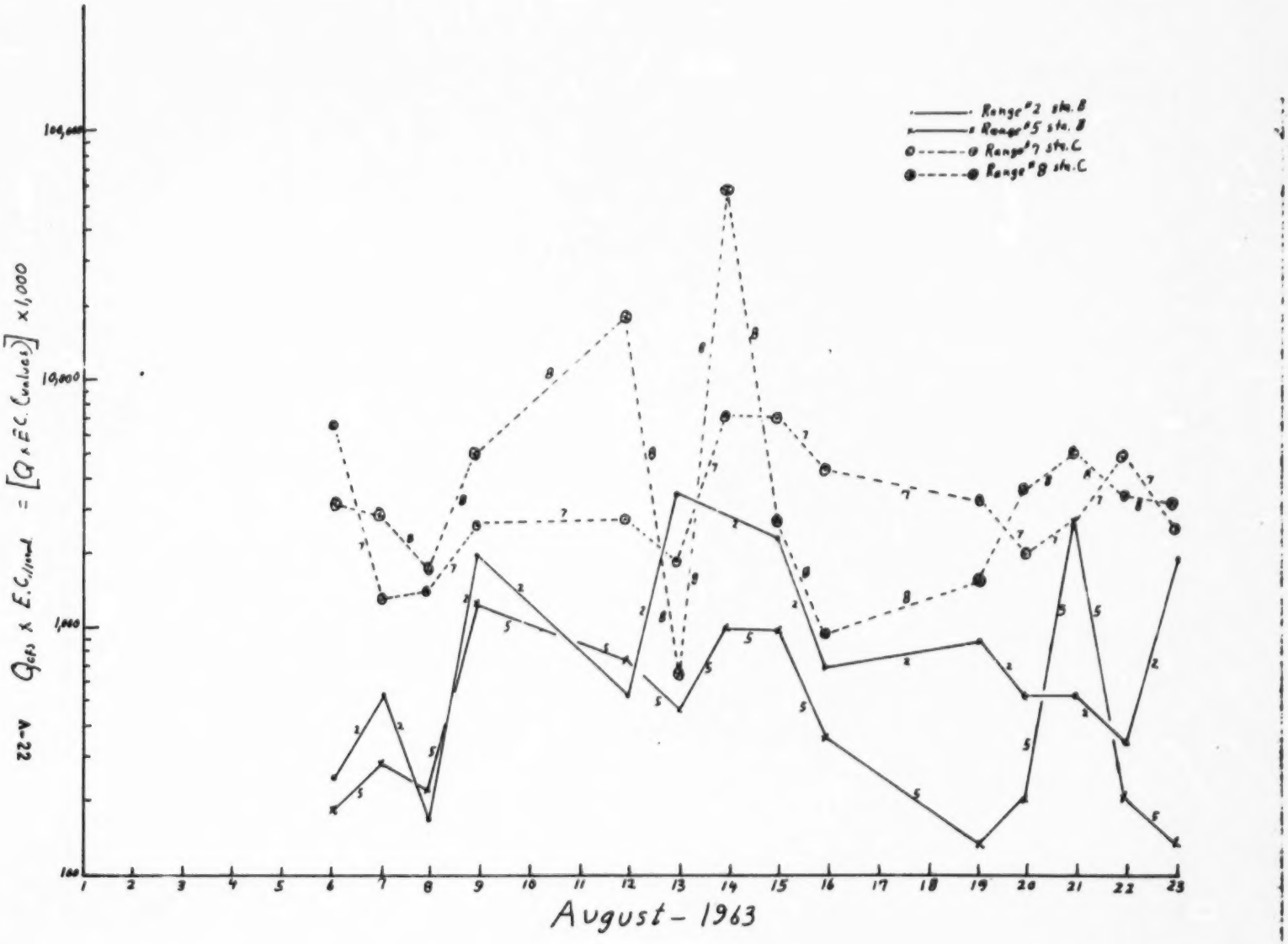
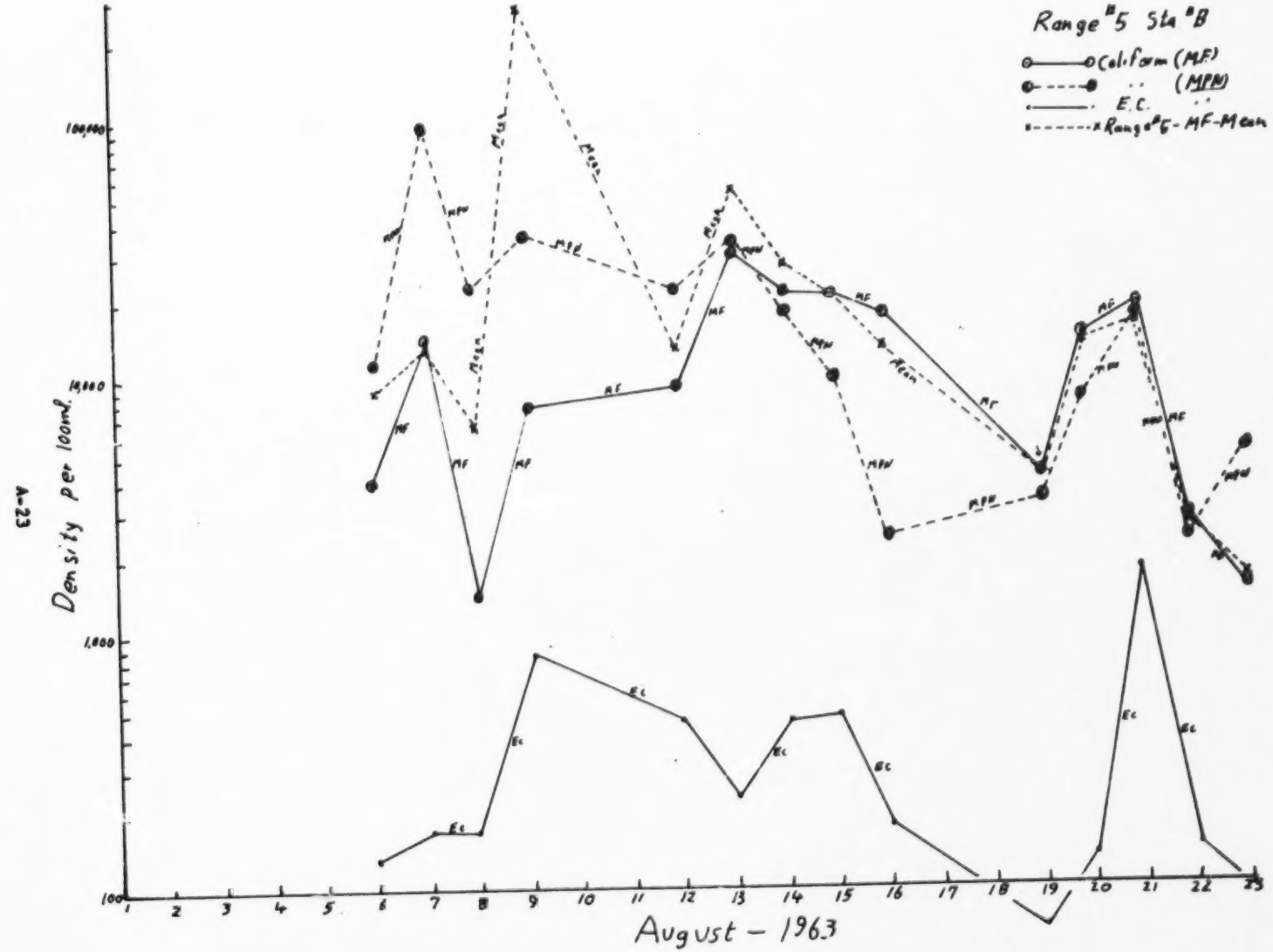
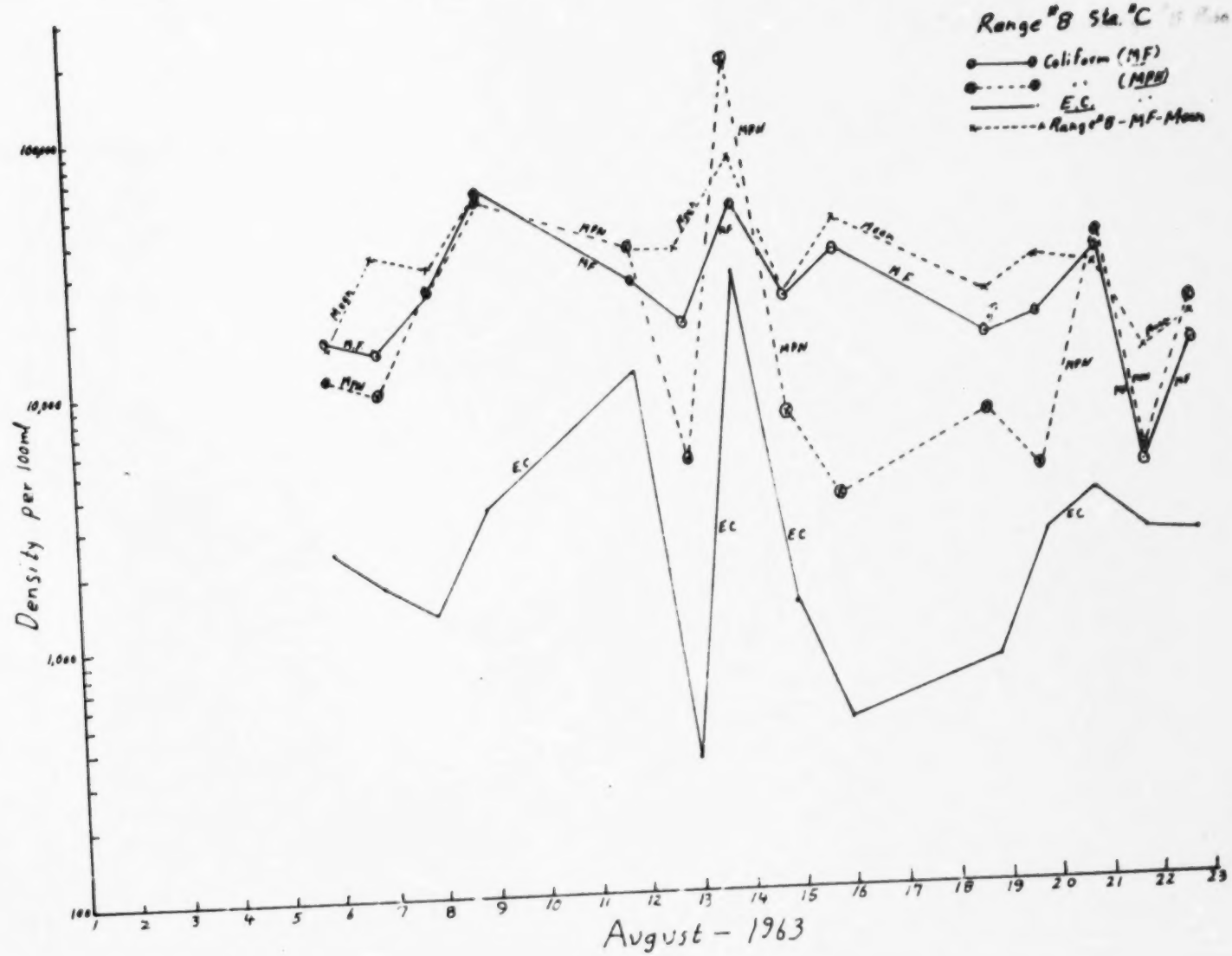
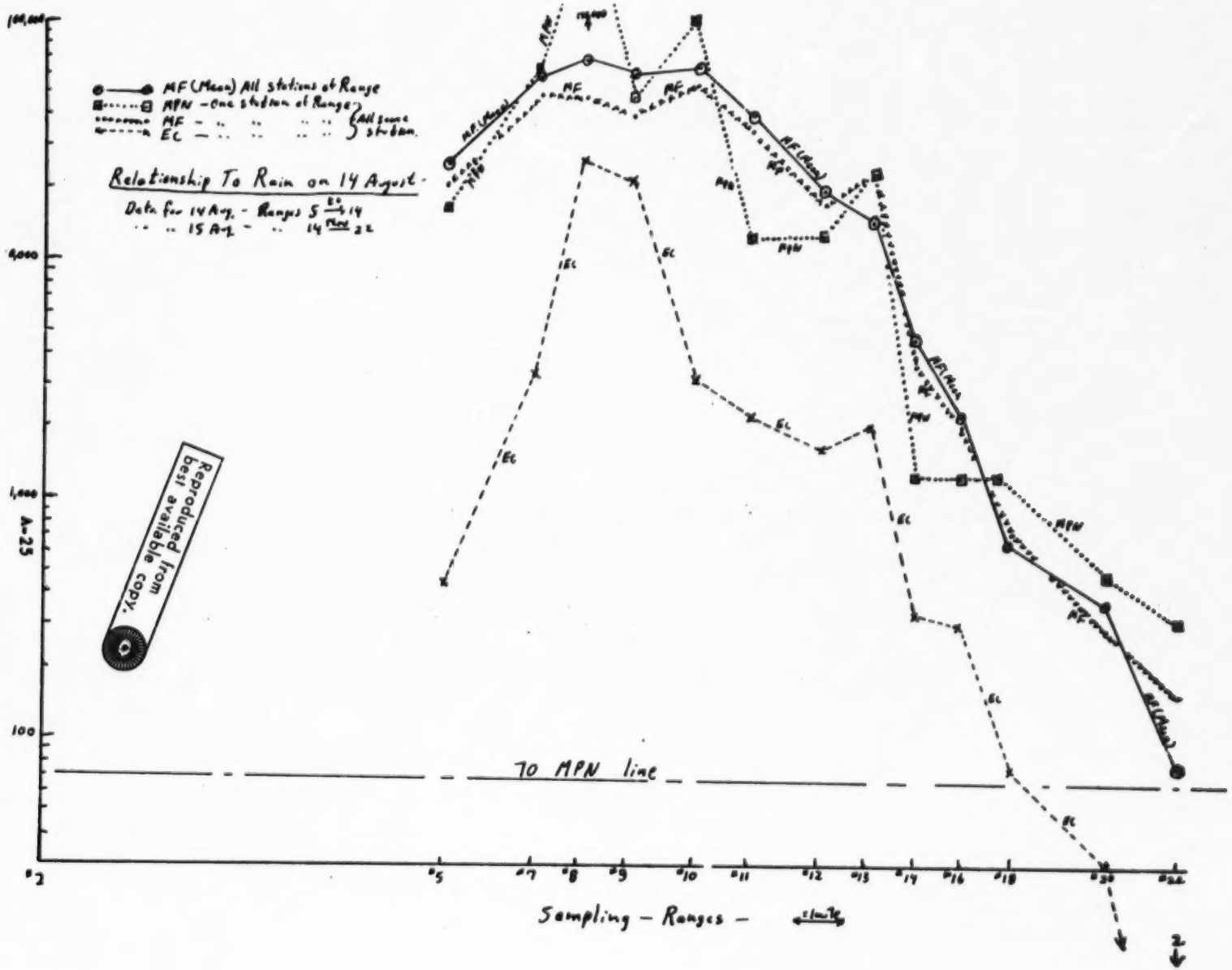

Percentage
5
10
15
20
30
40
50
60
70
80
85
90
95
10,000
1,000
100
Density per 100 mil
Range #7-63
Range #5-63
Range #7-62
Range #2-63
Range #5-62
Range #V-63
Range #2-62
Range #V-62



A-22 $Q_{cfs} \times E.C._{mmd} = [Q \times E.C.\ (values)] \times 1{,}000$


Range "5 Sta "B
Coliform (MF)
(MPN)
E.C.
Range "5 - MF - Mean
Density per 100ml.
100,000
10,000
1,000
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August - 1963


Range "B Sta. "C
Coliform (M.F)
(MPN)
E.C.
Range "B - M.F - Mean
Density per 100ml
100,000
10,000
1,000
100
MPN
M.F
EC
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
August - 1963


MF (Mean) All stations of Range
MPN – One station of Range
MF – .. .. } All same station
EC – .. ..
Relationship To Rain on 14 August
Data for 14 Aug. – Ranges 5 to 14
.. .. 15 Aug. – .. 14 Plus 22
100,000
4,000
1,000
100
A-23
MF (Mean)
MPN
EC
To MPN line
Sampling – Ranges –
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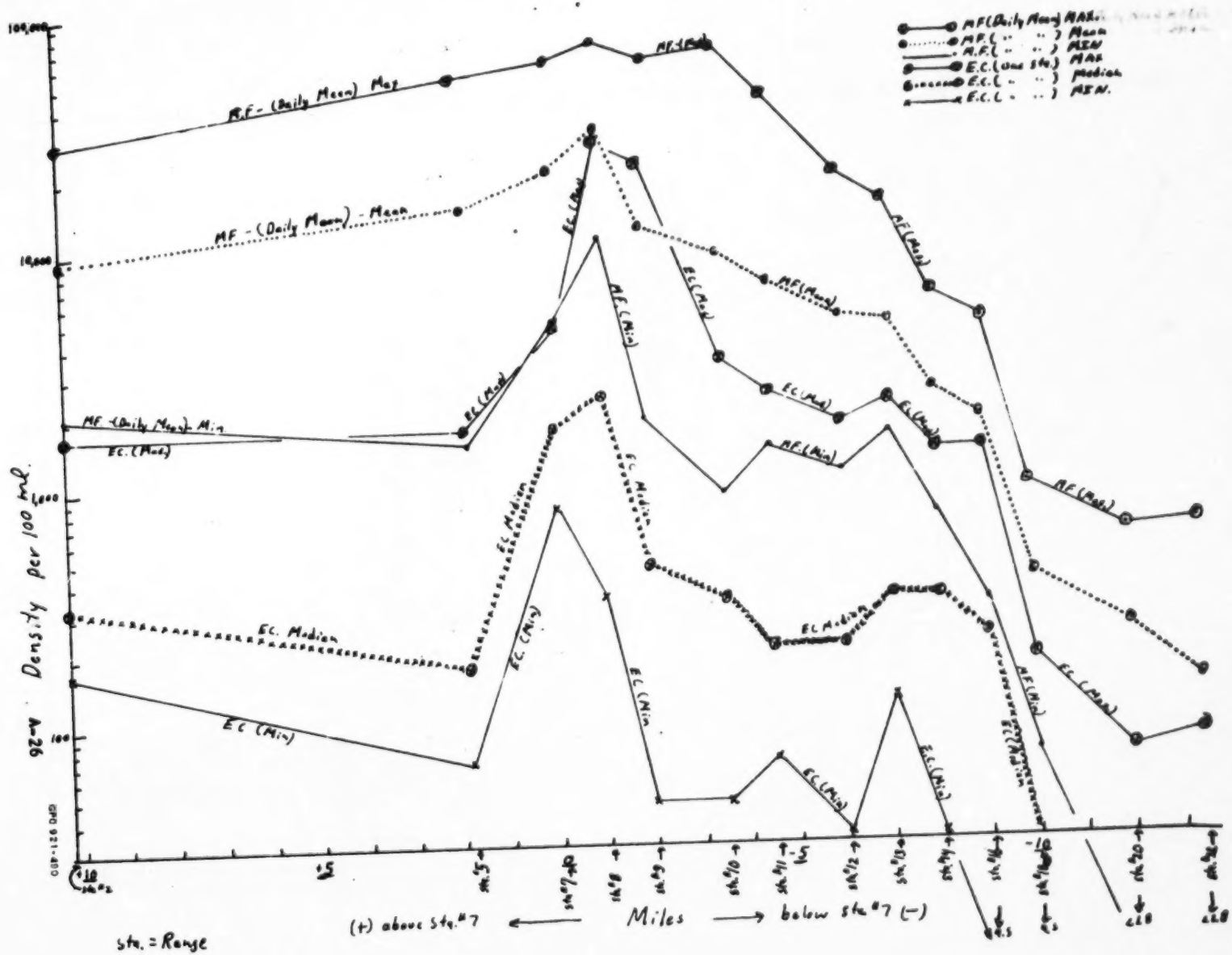
M.F (Daily Mean) MAX.
M.F. (" ") Mean
M.F. (" ") MIN
E.C. (one sta.) MAX
E.C. (" ") Median
E.C. (" ") MIN.
M.F. (Daily Mean) Max
M.F. - (Daily Mean) - Mean
M.F. (Daily Mean) - Min
E.C. (Max)
E.C. Median
E.C. (Min)
M.F. (Max)
M.F. (Mean)
M.F. (Min)
E.C. (Max)
E.C. (Mean)
E.C. Median
E.C. (Min)
100,000
10,000
1,000
100
Density per 100 ml.
A-26
GPO 921-480
sta. = Range
(+) above sta. #7
Miles
below sta. #7 (−)